# A Classification Model for Human Error in Collaborative Systems

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# Abstract


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The primary focus of the work reported in this thesis is to investigate and provide a means by which the occurrence of human error in collaborative systems can be better understood. The thesis suggests that much can be gained from looking at human error from a collaborative perspective as opposed to more traditional cognitive and behavioural approaches. The work is motivated through the failure of many human error analysis methodologies to fully capture and model the impact collaboration can have on the occurrence of human error. The basis of the work is the premise that human error can be examined and understood using accepted models of collaboration.

This thesis describes the development of a classification model for understanding human error in collaborative systems. It describes how a model of collaborative human error was conceived and how its elements were developed into a classification mechanism. The classification model was developed and tested through its application and examination to a series of reported and observed examples of collaborative human error. Through the development of the classification model a structured approach was developed to support its application. This structured approach incorporated a framework of standard techniques that were adapted for the research.

The issues raised in the research provide a means by which the complex nature of collaborative human errors can be broken down, enabling them to be understood and described. The model describes collaborative human error on three levels examining social issues, such as regulations, rules, beliefs, goals and historical factors; environmental issues, such as opportunities, interests and plans; and, issues of local interaction performed by user to complete a task. This unified approach provides a manageable way to investigate erroneous environments.

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*For my Gran, Joan Thatcher, who never understood what I was doing but who was always very proud.*

*"When through the woods and forest glades I wander*
*And hear the birds sing sweetly in the trees;*
*When I look down from lofty mountain grandeur,*
*And hear the brook, and feel the gentle breeze"*

# Chapter 1

# 1 Introduction

The research described in this thesis considers human error in collaborative systems. It asks questions concerning the nature of these two areas: how they affect each other; how they can be analysed; and the benefits that can be gained from examining the combination. These questions are addressed through the examination of case studies, error observations and the literature related to the field. The result of this work is a classification model through which human error can be understood, categorised and assessed. The premise investigated in this thesis is that human error in collaborative systems can be studied from a perspective of collaboration rather than from the more traditional theories of behaviour.

The thesis looks at human error from a perspective that incorporates many disciplines including business, psychology and computing. This broad approach is needed because of the complexity added by examining group environments. From such a perspective it is possible to understand the contribution to human error from collaboration between organisations, users and collaborative system technology.

In Section 1.1 of this chapter the context of the work is presented and Section 1.2 describes the background to the research by introducing the main areas requiring examination. Section 1.3 states the objectives of the work described in this thesis that show the novel aspects of the study. The research methods used to tackle these objectives are described in Section 1.4. Section 1.5 outlines the remaining chapters.

## 1.1 The Context of the Work

Collaborative systems are ones that facilitate a number of people working together to achieve a goal. The study of collaborative systems is not limited to the direct interactions made at the human-computer interface but also considers the social conditions surrounding the system which are reflected in the study of Computer

Supported Collaborative Work (CSCW) as described in Mantovani (1996) and Dix et al. (1998).

Collaborative systems are said to facilitate workgroup activities. Technologies built to support these workgroups should be designed according to the needs of the workgroup; the structure of the workgroup should not be dictated by the limitations of the technology (Gunter 1998). Due to the importance of social aspects in the study of collaborative systems, it is important to consider the people both directly and indirectly involved in the workgroup. There are many items present in workgroups that are influenced by people, groups and organisations external to the workgroup in question.

Collaborative systems are currently being studied in a diverse set of research domains such as education (Cadiz et al. 2000), ubiquitous computing (Grudin 2002), interactive television (Abreu et. al 2001) and the Internet (Klöckner 2002). With the growth of interest in these areas the term collaborative system is taking on new meanings. In ubiquitous computing, technology is intended to be as invisible as the pen with which we write a letter (Norman 1999). In the same way collaborative systems should allow us to interact with another person located anywhere in the world without even thinking about the technology facilitating the communication. The use of this technology increases the importance of examining the scope of study set out in the CSCW domain.

In this research the term collaborative system is taken as an umbrella term to incorporate the study of any socio-technical system facilitating collaboration and co-operation between workgroups and external parties. The collaborative system is likely to affect their interaction with the system and other agents. This umbrella term covers technologies such as collaborative information systems, groupware, workflow and process managers, ubiquitous technologies and the Internet.

The study of human error in collaborative systems is a new area of study and resources for the testing and evaluation of the research described in this thesis are scarce. This study utilises well-known examples of human error from case studies such as the Kegworth Accident and the London Ambulance Service Computer Aided Despatch

(LASCAD) system failure where collaboration is seen to be a major contributing factor relating to their occurrence and their consequences (Hancke 1995 and Beynon-Davies 1999). Some of these studies include examples of human error that do not directly involve computer-mediated collaboration but assist in providing an understanding of how human error can occur in collaborative environments. Other studies include observed case studies that originate from this research and that directly involve the use and implementation of collaborative systems.

The implication arising from studying human error in a collaborative system context results in a need to review what is meant by the term human error and the scope that such a study requires. Bogner (1995) states that a human error is:

> *…an act, assertion, or decision that deviates from a norm and results in an actual or potential adverse incident. That incident may or may not eventuate in an adverse outcome. The norm which defines an error is consensually accepted by the constituents of the domain under consideration. An error may reflect a number of factors or may be the final act in a series of contributing errors, i.e., a cascade of errors.*
>
> *Bogner 1995 (pg. A-24)*

This definition focuses on a norm and deviations from it. The definition is a good one because it also defines what a norm is and that it is established through some form of collaboration. However, there are likely to be new areas of context where norms may not currently exist. The definition also recognises that the human error can consist of a number of smaller errors which all contribute to its occurrence which is an important issue when looking at human error in context and in team environments. The definition is also important in that it recognises the importance of foreseeing the potential for errors in situations that are, in their current state, not erroneous. The problem with this definition is that a deviation from a norm may not be erroneous. In some situations it may be necessary to deviate from a norm in order to prevent human error or to make a process more efficient. The definition includes many of the important facts in a useful definition but is trying to be too inclusive as just one term.

This examination of a human error definition in the context of collaborative systems highlights the following implications for this research:

1) The complexity of studying group work as opposed to studying the work of a single person results in added complexity for the study of human error in group environments.
2) Norms may differ from person to person and group to group. It is not necessarily the case that either consensually accepted norms exist or that they are appropriate for all team members or external parties connected to the group.
3) Erroneous situations can occur through a sequence of human errors. These errors may result as a consequence of each other or may be made by different parties involved in the task.
4) Due to the social nature of collaborative system environments a study of human error should consider the impact that social factors have on the occurrence of human error.
5) The potential for disparate situations that exist in collaborative systems means that situation context should be a major contributing factor when studying human errors in collaborative system environments.

These issues suggested that a primary focus of this research should be to develop a more complete understanding of the occurrence of collaborative human errors. The initial stages of gaining this understanding would be to explore possible definitions of collaborative human error, a model by which their occurrence can be described and a classification to distinguish between different types of collaborative human error.

## 1.2 Background

From the 1970s human error became a more popular topic for research especially after human intervention was attributed as a contribution to Flixborough in 1974, Three Mile Island in 1979, Chernobyl in 1986 and Kegworth in 1989 (Reason 1990). After the realisation of the impact on accidents human intervention has, human error classifications and analysis techniques were devised, for example Norman (1981) and Reason (1987). These techniques were confined to the examination of the cognitive theory behind individual actions (Viller 1999). However, recent research directions have shown that studying errors in this way is of little value in understanding the wider context. More recent studies have focused on the impact of contextual issues on human error (McCarthy et al. 1997). Unfortunately this has had little impact in increasing its application to industry (Johnson 1999b). This means that further work is required in this area to improve human error analysis.

Research on human error can be found in a number of varying disciplines such as business (e.g. Smith 1996), transportation (e.g. Air Accidents Investigations Branch 1990), psychology (e.g. Norman 1981), sociology (e.g. Hughes et al. 1992), medicine (e.g. Felciano 1995) and computing (e.g. Fields et al. 1995). Each discipline looks at human error from a slightly different perspective. In business the focus is on business strategy, risk analysis and why strategies may fail, in transportation the focus is on major accidents such as aircraft crashes and in psychology the focus is on the cognitive aspects of human error. Over the last ten years aspects of human error research from psychology and transportation have been incorporated into the field of computing. The study of human error in computing is still a relatively small though expanding area. The research described in this thesis is mainly based on examining human error in the discipline of computing, however, due to the emphasis on collaboration, it draws on elements emerging from each of these disciplines. Not all human error examples in this thesis are computing examples but are used to gain an understanding of how human error occurs in collaborative environments.

Reason (1997) states that there are two kinds of accidents, those that happen to individuals and those that happen to organisations. Studies have been conducted on the occurrence of human error in organisational settings (Reason 1997 and Beynon-Davies 1999). The term 'accident' refers to an error that has serious, and often life threatening, consequences. Another term, 'incident' that is not referred to in much organisational error research refers to errors that result in minor consequences.

Although some human error researchers do introduce elements of collaboration into their studies, it is not the main emphasis. Research focusing on human error in collaborative systems is a relatively unexplored area of study though it is an area that has been touched upon often. From the collaboration side some work has been carried out as to why groupware systems fail (Grudin 1988 and 1995 and Newman and Newman 1992) and many of these failures are as a direct result of human intervention though no references are made directly to human error. Twidale and Marty (2000) state that, with the exception of a few examples including Trepess and Stockman (1999), relatively little attention has been in the CSCW literature to the role of errors in the design and use of collaborative systems.

Identifying issues of use in collaborative systems, in the form of Computer Supported Co-operative Work (CSCW), has become a popular area of research interest. Research has been conducted in many areas such as:

1) Designing frameworks for the design and use of collaborative systems (Dix 1994, Mantovani 1996, Salvador et al. 1996 and De Michelis et al. 1997);
2) Creating classifications for and understanding workspace awareness (Gutwin et al. 1995 and 2001, Pinelle et al. 2002 and Ljungstrand 2000);
3) Understanding norms and conventions in CSCW systems (Pankoke et al. 1999 and Liu and Dix 1997)
4) The design of tools facilitating effective collaboration such as TeamWave (Greenberg et. al 1998) and Virtue (Schreer and Kauff 2002); and
5) Understanding behavioural aspects of interacting with collaborative systems including Grudin (2001)

Although these research areas encompass issues into the levels of usability of collaborative systems very few refer to any research from the human error field.

Major accident analyses such as those performed in the cases identified at the beginning of this section do look at collaboration as a factor but it is not the central focus of the analysis methodology (Reason 1999). Many use methods described by Reason (1987) and Hollnagel (1993) which are not based on the collaboration aspect of human error and are not related, specifically, to computer systems. Much of this research has been done with the aim of assessing causality but more recently research has been conducted with other purposes in mind. An example of this is the work focusing on the usability aspects of determining conclusions from accident reports (Johnson 1999a).

This section indicates that looking at human error in collaborative systems, henceforth known as 'collaborative human error', is a relatively new area of study. The section does not make any references to the issues of doing such a study but these will emerge throughout the thesis. What is shown here is that human error analysis has changed over the last twenty years and there are many areas that require a greater understanding. For example, context is being viewed as an important aspect of study in recent research. This can relate to the context of the task, the physical environment and the interactions between users. It is also important not to forget the incidents that occur so much more frequently than the more high profile accidents that are such a popular forum for research and that show recovery paths.

## 1.3 Objectives of the Research

The primary objective of the research described in this thesis is to examine the occurrence of human error in collaborative systems and to identify a viable alternative to the way in which human error can be examined with an emphasis on collaboration. This objective can be broken down into the following sub-goals:

1) To identify the issues involved in adopting a collaborative focused approach.
2) To present a developed understanding of how human errors occur in collaborative systems within a model and classification.
3) To demonstrate how a collaborative systems focus can be used in the examination of human errors in real world environments.
4) To identify the issues of putting a collaboration focus in human error analysis. This explores the validity of the model, the issues of its application and the applications in which such an approach can be utilised effectively.

## 1.4 The Research Approach

The objectives set in the previous section of this chapter were to explore the implications of studying human error with a focus on collaboration as opposed to behaviour. The research approach adopted to examine these aims and objectives is one implied from the discussions edited by Senders and Moray (1991) which includes the following stages:

1) Conduct a literature review in collaborative systems and human error;
2) Construct a model of human error occurrence.
3) Develop a classification based on the elements that exist within the model;
4) Develop the model and classification through their application to examples of human error in collaborative systems.
5) Apply the model and classification to examples of human error to illustrate how the model can be used to examine human error and to further assess its validity.

These stages provide an overall structure that is used to guide this study and they are reflected in the structure of this thesis. An early indication from a review of human error literature suggested that a combination of observation and textual analysis of case study material was best suited to examining human error in real world environments. However, the common research approaches in collaborative systems are somewhat different. In collaborative systems the popular research approaches appear to be based on experimentation, ethnography, conversation analysis, activity theory (Nardi 1996), organisational analysis (Reason 1997) and action research (Collins 1995). The unpredictability of errors makes studying them difficult using commonly found approaches to collaborative system research. The approach is also complicated by the emphasis on collaboration. This led to an approach that combined elements common to human error research and collaborative system research.

Combining research approaches used in these two fields is of interest in itself but is only discussed here in relation to the ability of the combination to address research objectives. The combination of approaches used consisted of observations, textual analysis, experimentation and action research.

***The first objective*** to examine the occurrence of human error in collaborative systems and to identify the issues involved in adopting a collaborative focused approach was addressed through conducting a detailed literature review. This literature review covers the examination of collaborative systems and human error. Collaborative systems are examined in terms of identifying the scope of study that is necessary in this domain and the issues of use arising within it. Human error is examined in terms of the applicability of current approaches to collaborative systems and the requirements for developing and validating a new human error approach.

***The second objective*** to develop an understanding of how human errors occur in collaborative systems is addressed through the examination of human error scenarios in relation to an accepted framework for collaboration. Through studying how human errors occur in relation to different elements of a collaborative framework, it is possible to gain an understanding of the mechanisms that exist in collaborative systems that impact upon the occurrence of human error. From this examination it is possible to develop a model for human errors in collaborative systems by extending the collaborative framework to cater for human error and develop a classification for their description.

***The third objective*** is to demonstrate how a collaborative systems focus can be applied in the analysis of human error in real world environments. This is addressed by the application of the collaborative approach to examples of human errors. This research uses example errors from both reported case studies and from observation studies to illustrate the application in domains that are both well known and that have never previously been studied. The reported case studies are taken from accident and incident reports. The observed errors are obtained from a groupware experiment and from the implementation and use of an international groupware environment. This objective is demonstrated through the structured application of the model and classification using a framework of techniques that are common to human error approaches

Textual analysis is a well tried approach adopted by researchers interested in large-scale human error examples such as the analysis of major accidents (Johnson 1997, Smith 1996 and Fields et al. 1995). The reported material in this research is accident and incident reports written by official inquiry teams such as the Air Accident Investigation Branch (AAIB).

Observation, or naturalistic corpus gathering, is a widely applied approach used in early human error studies right through to current research. The approach can be seen in Norman (1981) who identified a classification of action slips that categorised different unintentional actions. In more recent work, observation is used in studies by McCarthy et al. (1997) who examined contextual elements of human error and Chambers et al. (1999) who examined incidents involving safety related systems.

***The fourth objectiv****e* to identify the issues of putting a collaboration focus on human error analysis is addressed by examining the results and application of the case study analysis. This examination is conducted in relation to how it can be applied and what are the issues of its application.

## 1.5 Outline of Chapters

*Chapter 2* provides an overview of the literature found on human error and collaborative systems. The chapter explores research into human error techniques and collaborative systems and the directions it has taken over the last twenty years. There follows an examination of what is involved in analysing human error in collaborative systems and how these systems can complicate an analysis. The chapter also examines some areas where advances in current human error research need to be made. Finally, the study identifies current application areas for the results of human error analysis.

*Chapter 3* describes the initial phase of the research to identify how human error can occur in collaborative systems by a basic examination of example human errors in relation to a framework for collaborative work. The result of this chapter provides the basis for a classification model which gives some understanding to how human errors occur in collaborative systems and to identifying the issues involved in such an approach.

*Chapter 4* describes the classification model and classification that was produced from the studies conducted in this research. This identifies the key components of human errors in collaborative environments. The model provides the basis of demonstrating how a collaborative focus can be used in the examination of human error in collaborative systems. An application framework is also described in this chapter that was used to apply the classification model. The model and classification that are presented in this chapter provide a means of understanding how human error occurs in collaborative environments.

*Chapter 5* describes the approach that was adopted in this study to derive and examine the classification model proposed in this research. The research describes three main phases:

1) Explore the fundamental aspects of a model of collaborative human error.
2) Develop the classification model on reported case studies.
3) Apply the classification model on observed examples of erroneous situations.

*Chapter 6* describes the application and development of the classification model through Phase 2 which describes the application and development of the classification model on reported case studies including the Kegworth Accident case study and the London Ambulance Service Computer Aided Despatch system (LASCAD) case study. These case studies are both used to further develop the classification model.

*Chapter 7* describes Phase 3 of the research approach that examines the development of the classification model through its application to observed examples of human error. The phase examines errors observed in a groupware experiment and in the implementation and use of an international groupware environment. The first study in this phase examines examples of collaborative human error observed in a collaborative diagram building task. The second study in this chapter examines human errors examined in the implementation and use of an international groupware environment (WitStaffs).

*Chapter 8* draws conclusions on the work described in this thesis. Summaries are given describing the contribution the research gives to the human error and collaborative system communities and a discussion is given of how the approach relates to current understandings of human error. Finally, an outline is given of possible areas for future work.

# Chapter 2

## 2 Human Error and Collaborative Systems

This chapter examines the literature relating to human error and collaborative systems. This examination sets the scene for the remainder of this thesis through exploring issues involved in these domains and identifying research questions to be addressed. Research into human errors has been progressing for many years including studies by Norman (1981), Rasmussen (1987), Maurino et al. (1995), Fields (1995) and McCarthy et al. (1997). However, very little research has investigated the occurrence of human errors in collaborative systems. Research has, in the past, been dominated by studies of individual operators interacting with individual systems (Johnson 1999b and Viller et al. 1999). There has been a reluctance to extend these studies to deal with more complex, and more common, team based interaction though many have expressed it as an important issue (Woods et al. 1994, Reason 1997, Johnson 1999b and Twidale 2000). The aim of this chapter is to identify research questions associated with a collaborative system focus of human error.

Section 2.1 considers the need for a collaborative focus of human error analysis. This section considers the aims of current human error theories and their focus. It also identifies failure examples to show how collaboration plays a vital role in their occurrence.

Section 2.2 examines collaborative systems in order to gain an understanding of the implications that they introduce for the study of human error. This examination is addressed through looking at literature in the field of collaboration and collaborative systems. This area is approached by examining the levels and components of collaborative system frameworks relating to their use.

Section 2.3 introduces the study of human error. This includes an examination of the definitions provided for human error, the theories and classifications used for its analysis and the uses for which analysis products can be adopted. The section discusses the focus of human error analysis and its relative inability to be applied to collaborative systems.

Section 2.4 presents a discussion of what the issues are of a collaborative system focus on human error and what are the aims of such an analysis. These issues and aims are translated into research questions to be addressed through the remainder of the thesis.

## 2.1 The Need for a Collaborative Focus of Human Error

The purpose of this section is to examine the need for a collaborative system focus on human error analysis. This is addressed by identifying the impact of collaboration on groupware system failure and on the occurrence of major accidents.

In collaborative systems such as those dealt with in the field of CSCW the element of collaboration will have a major impact on the occurrence of human error. A clear example can be seen in the electronic calendar software described by Grudin (1995) described in the extract in Figure 2.1.

> …a study conducted in a large organization that developed and marketed an early electronic calendar identified factors that contributed to a lack of use of the meeting scheduling feature (Ehrlich, 1987a; 1987b; Grudin, 1988). Electronic calendars were used as communication devices by executives, managers, and their secretaries, but only by about one in four individual contributors. The latter, if they kept any calendar at all, found portable paper calendars more congenially available in meetings, for example. To maintain an on-line calendar would require more work of individual contributors, but the direct beneficiaries would be the managers and secretaries who called most meetings. In addition, although most employees had computer access, not everyone in the organization was networked tightly enough for the software to reach them. As a result, meetings were scheduled by traditional methods, despite the presence of the software on everyone's desks.
>
> *Grudin 1995*

Figure 2.1: Extract from Grudin (1995) describing a collaborative system failure

This example shows that there was a lack of collaboration due to the fact that the electronic calendar software was not available to all contributors and that some contributors preferred more portable paper calendars. This shows a clear example of where a lack of collaboration in accepting the system led to the software not being used.

Collaborative systems do not only relate to those systems traditionally under the heading of CSCW but also relate to any system that is used by or has an effect on other people. Large-scale failures in these systems can be seen through accident and incident reports. Many accidents and system failures have been attributed to human error (Woods et. al 1994). Hollnagel (1993) states that the number of reported accidents that can be attributed to human error in 1960 was an estimated 20%. In 1990 this figure is believed to have increased to over 80%. It has to be remembered that since 1970 the focus on human error has become more prominent and so more accidents and incidents are being attributed to human error. Even though these figures are only approximations the difference between the two figures is still concerning and stresses the importance of examining the occurrence of human errors. It can also be estimated that a high percentage of these accidents were influenced by and had effects on more than one person and that the accident was due to a lack of collaboration in some way (Reason 1997 pg. 20).

Examples of where multiple agents contribute to accidents and incidents can be seen in the Three Mile Island accident (Presidents Commission 1979), the Kegworth Accident (AAIB 1989), the London Ambulance Service system failure (South West Thames Regional Health Authority 1992) and the Herald of Free Enterprise accident (Sheen 1987). These safety-critical systems are invariably collaborative to some degree in the nature of their management and use (Viller et al. 1999 and Woods et al. 1994). This section does not go into detail in describing the impact that collaboration, or lack of it, had on these cases as this requires detailed analysis. The Kegworth Accident and the London Ambulance Service system failure are described in more detail in Chapter 6 of this thesis. The contribution that collaboration has on an accident or system failure can range from an organisation failing to provide a procedure for a certain event as in the Kegworth accident to a simple lack of communication.

Even though much research has been conducted in the development of human error methods and frameworks they are still not widely accepted in industry (Johnson 1999b). In Johnson's 1999 paper he gives a list of ten reasons why human error analysis is not as useful as it should be:

1) There is little methodological support for human error analysis.
2) Human error modelling techniques depend upon subjective interpretation of experts.
3) Many techniques explain the causes of human error but do not support "run-time" predictions.
4) Many techniques explain human error but do not support "design-time" predictions;
5) There has been a focus on human error in major incidents rather than lower impact incidents.
6) The focus has been on individual failures rather than team errors with concurrent systems.
7) The focus has been on operational errors rather than regulatory failures.
8) It is hard to consider organisational sources of error in conversational requirements analysis.
9) Few techniques help designers to reach consensus on the contextual sources of latent failures.
10) Too little has been done to reduce the scope for error during error analysis itself.

In this list is a requirement to support team errors in concurrent systems which relates to the research in this thesis. This is enforced by Woods et al. (1994) who state that elements of human error "…do not apply just to an individual, but also to teams of practitioners". Woods goes on to say "One of the basic themes that has emerged in more recent work on error is the need to model team and organizational factors" (Woods et al. 1994, pg.6). The list also contains other issues that need to be addressed in human error research such as the consideration of organisational sources of error in requirements analysis. This list provides a good indication of where current analysis techniques fall short and is useful in setting the research questions addressed in this thesis. These issues are discussed in more detail later in Section 2.3 of this chapter.

What emerges from this section is confirmation that there is a need for a human error approach to accommodate human error in collaborative systems.

## 2.2 Understanding Collaborative System Use

Research into collaborative systems has been progressing at an increasing rate over the last ten years. There is now such a large scope of research in this area that it is impossible to review all different areas of collaborative systems. The aim of this examination is to explore the differences between collaborative systems and single user systems in terms of their usage and to examine what makes studying collaborative systems so complex.

This section identifies the complex issues that have to be addressed in the design and use of collaborative systems. This is achieved by examining issues relating to three levels of context set out by Mantovani (1996) that provide a holistic view of these systems (see Figure 2.2).

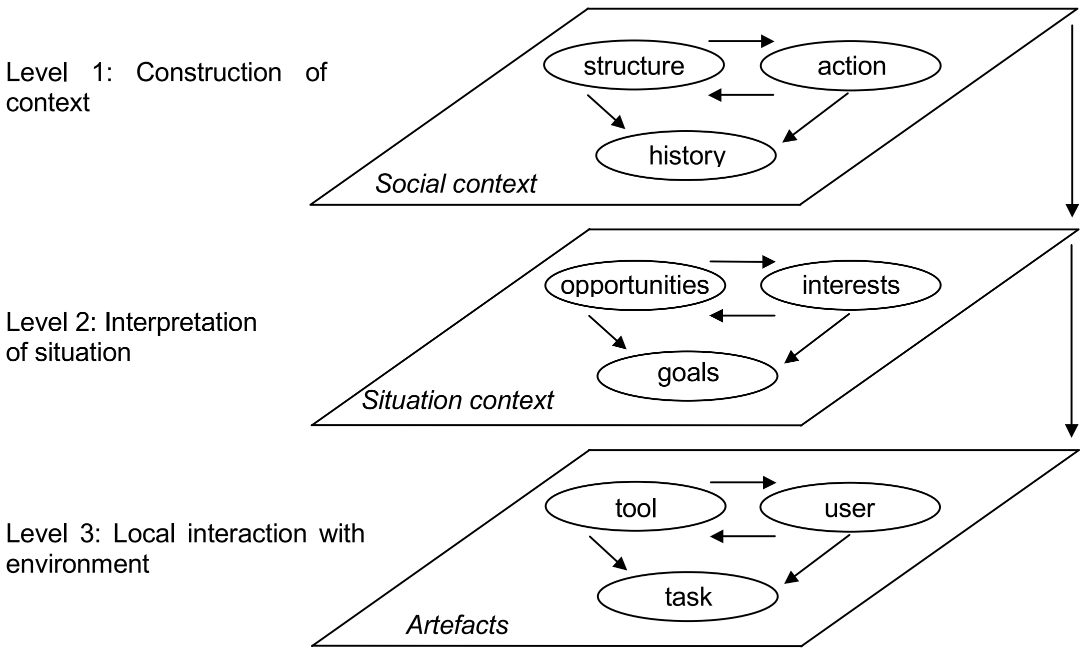


Figure 2.2: Mantovani's three-level model of social context (Mantovani 1996).

Similar concepts can be seen in Figure 2.3 (De Michelis et al. 1997) which confirms that the study of collaborative systems extends to that of the organisational facet. The reason that Mantovani has been chosen for this analysis of collaborative systems is that Mantovani provides structures of concepts working together to form a product within each level which provides a focus on usage whereas De Michelis' approach is concerned more with issues of collaborative system design. It is important in the domain tackled in this thesis that there is a focus on collaborative systems usage though the design issues are also important considerations.

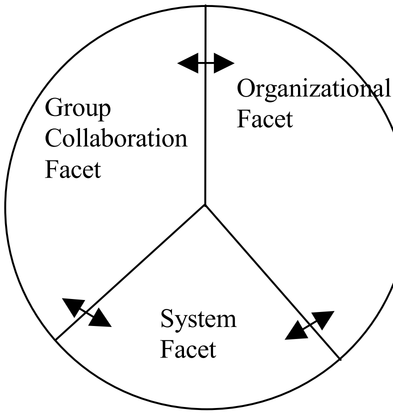


Figure 2.3: The three facets of co-operative information systems (De Michelis et al. 1997)

The levels are examined in reverse starting from Level 3 and working up the framework to Level 1. The purpose of this is to initially illustrate the difference between single user systems and multiple user systems and then elaborate on the issues in the other two levels of the framework. From conducting the examination of these areas it is possible to clarify issues of collaborative systems effecting human error analysis.

From Mantovani's framework (Figure 2.2) it can be seen that in contrast to conventional frameworks it flows from the top down and takes the system in the context of the social environment and not the social environment in the context of the system. Past frameworks for CSCW have put the emphasis on the CSCW tool, such as the time/ space matrix (Dix 1998) and framework for CSCW artefacts (Dix 1994). Little consideration has been put on the social context and thus it loses sight of the functional characteristics of a task and the system's real use (Mantovani 1996). Much research has been conducted at each of these levels and this is incorporated in the following sections examining each level.

### 2.2.1 Local Interactions with the Environment

In relation to this level there are three concepts that are considered which are tools, users and tasks. Research has been conducted in the development of groupware tools and how a user conducts tasks in order to use them. This section is split into two parts that deal with each of these two issues.

#### 2.2.1.1 Tools for Groupware

In Mantovani's framework tools, or artefacts, are referred to as '…objects created to serve a purpose, which is inscribed in them' (Mantovani 1996). Another definition is offered by Salvador et al. (1996) who states that artefacts refer '…to those objects produced and consumed during interaction.' Salvador et al. also state that there are five generic artefact types consisting of:

1. Text, which relates to written language;
2. Sound, which relates to any information presented aurally or via audio media;
3. Temporal image, which relates to images that change over time; and
4. Static image, which relate to non-text graphics that remain in the same state; and
5. Computational elements, which relate to tools which have computational capabilities.

This generic group offers support for both conceptual and physical objects which means that an object can relate to a piece of information that is spoken or thought as well as an object physically created to perform a task. In collaborative systems this generic group supports artefacts incorporated into computational tools such as sound and temporal image in video conferencing systems and text in email systems. This combination of artefacts is known as compound artefacts.

The computational elements refer to the collaborative technologies that are used and the tools that they include. Terzis and Nixon (1999) identify eight categories of collaborative systems that include:

1) Electronic mail systems: Facilitates simple messaging between individuals and groups. Include email and newsgroups;
2) Conferencing systems: Facilitates synchronous communication between distributed individuals. Includes video conferencing and text based chat systems;
3) Meeting support systems: Conferencing systems that facilitate application and data sharing through shared workspaces;
4) Group support systems: Facilitates advanced messaging systems, document management, calendaring, group scheduling, task management and workflow;
5) Groupware environments: Environments for scaleable, distributed teamwork that provide the necessary collaborative tools for specific tasks to be conducted;
6) Group Decision Support Systems (GDSS): Implementation of knowledge management tools in groupware environments to track and assist the decision making process;
7) Workflow applications: Facilitates the appropriate flow of information through an organisation making it accessible to the individuals it applies to; and
8) Shared editors: Provides facilities for multiple agents to work on the same object. Includes shared text editors, whiteboards and drawing packages.

In single user systems the production and consumption of tools is performed by an individual. In groupware systems these tools are shared and are produced and consumed by more than one person. This sharing has many implications in complicating interactions with the system which is discussed throughout this section.

#### 2.2.1.2 Users and Tasks in Groupware

In Mantovani (1996) a 'user' is simply a person involved in the interaction. In Salvador et al. (1996) the user is described as an entity that has characteristics such as a name, appearance, voice, address, primary language, a culture and interests. Many of the implications of these characteristics are dealt with at higher levels of Mantovani's framework. However, in relation to the tools, discussed earlier, many of these characteristics cannot be communicated easily. One of the reasons for this is that many of these characteristics are dynamic and are constantly changing.

A task as described by Mantovani (1996) is the dynamic character of computer systems use. Salvador et al. (1996) state that a task consists of four categories which are:

1) Goals, relating to high-level work objectives that guide all behaviours in the workplace;
2) Tasks/ scenarios, relate to high-level representations of the type of work that occurs in an environment;
3) Activities, relate to the basic communication interaction unit; and
4) Operations, relate to the basic interface manipulation unit during the communication.

In relation to Mantovani's framework this list of categories does not strictly fit. This is because goals are formed at level 2 and it is just the final three categories that occur at this level.

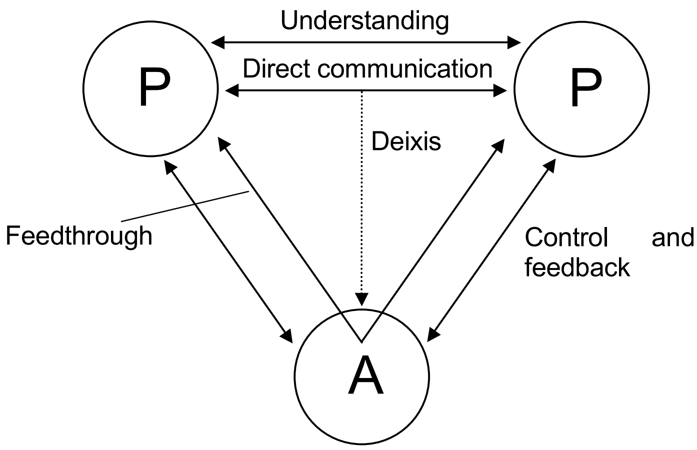


Figure 2.4: Framework for CSCW artefacts (Dix 1994)

The framework seen in Figure 2.4 by Dix (1994) can be used to illustrate how users perform tasks in collaborative systems. The use of the word 'artefact' in this framework relates to an electronic or virtual object that is being produced and consumed by users. Other conceptual artefacts, as defined by Salvador et al. (1996), are implied through direct communication. Tasks are implied through direct communication and through control and feedback. Co-operation begins with two people communicating with each other and successful communication means coming to a mutual understanding. In Figure 2.4 this is displayed by the relationship between P↔P. In communication there is always some artefact (A) that is involved in the communication. In some cases only one actor has access to an artefact and will get feedback from the artefact and communicate it to the other actors. Communication can also be made through the artefact itself for example in shared workspaces with multiple cursors. Through the communication between the actors references will be made to the artefact. These references are known as deixis.

### 2.2.2 Interpretation of Situation

Level 2 (Figure 2.2) examines the interpretations of the situation by looking at the context of the situation through opportunities, interests and goals. Opportunities arise through observations of certain environmental states. However, many opportunities are not seen unless other actors identify them. This may be because all people have different interests, all of which have different levels of priority. The priority of interests may be influenced by the social context. Goals are created through the relationship between opportunities and interests. Ellis and Wainer (1994) highlight the importance of representing the goals of individuals, groups and organisations within the design of CSCW systems and thus it is also important to recognise them when examining their use. Most of the discussion in this section relates to opportunities as interests and goals are dependent on the intentions of the collaborating group.

The equivalent of this level in De Michelis et al (1997) is the group collaboration facet. The main features of this facet are the levels of synchronicity provided by the shared workspace. However, there are many other issues that relate to group collaboration that are brought out through examining opportunities, interests and goals available.

The focus of the work by Endsley (1995) is on situation awareness, in both collaborative and single user environments, as a state of knowledge based on an assessment of the processes used to achieve that state called a situation assessment.

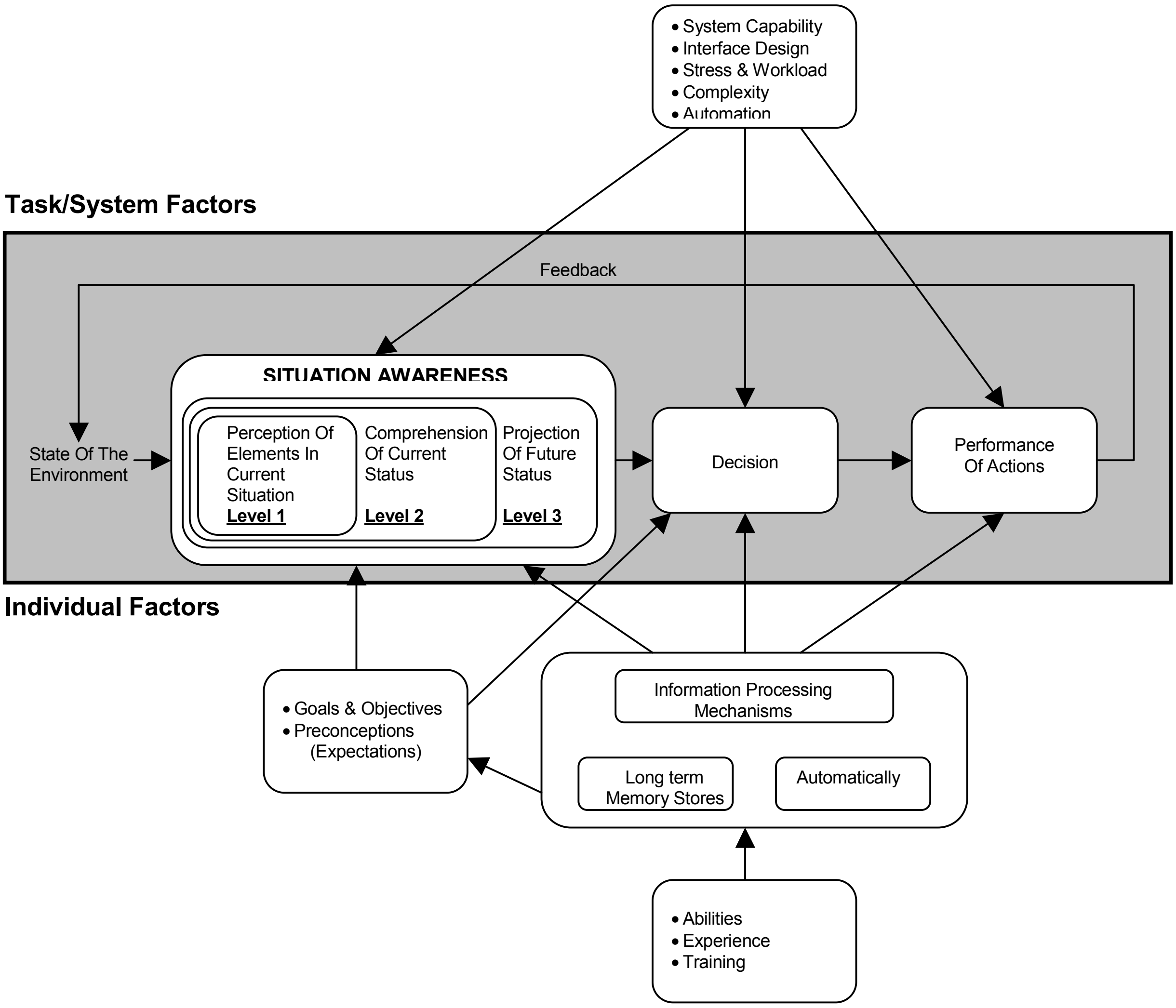


Figure 2.5: Model of situation awareness in dynamic decision making. (Endlsey 1995)

According to Endsley situation awareness consists of three levels (Figure 2.5):

1. Level 1 SA: Perception of the elements in the environment, relates to what a person can see, hear, feel, smell or taste.
2. Level 2 SA: Comprehension of the current situation, relates to understanding the significance of the perceptions made in level 1 in the context of the goal.
3. Level 3 SA: Projection of future status, relates to the ability to predict the future state of an object from the comprehension at level 2.

The elements that will have an impact on the situation awareness of an individual user consist of goals, objectives and expectations, which in turn come from their abilities experience and training. The elements that form the situation originate from the system capabilities, interface design, stress and workload, complexity and automation. For each user of a collaborative system the perception, comprehension and projection of the elements in the environment will be different. The difference according to Mantovani's framework originates from the differences in interest that each user has but there is also likely to be some overlap due to the general interest in the task.

This section discusses the situation context from two different perspectives of artefacts and the opportunities they offer. The first looks at the opportunities presented to users in terms of the presence of physical artefacts and users. The second part examines the opportunities presented by conceptual artefacts arising through either direct or indirect communication between users. Such conceptual artefacts consist of elements such as trust and user awareness.

In both parts situation awareness is shown to play a vital role. In part one workspace awareness (Gutwin et al. 1995 and 2001) is examined in respect to the awareness of what actions are being made with artefacts and by whom. In the second part task awareness (Gutwin et al. 1995 and 2001) and situation awareness in dynamic decision making (Endsley 1995) are discussed. Endsley uses a definition of situation awareness that states:

> *Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.*
>
> *Endsley 1995 (pg. 36)*

This definition also applies to the work of Gutwin et al. discussed in this section. In examining the definition in terms of opportunities, interests and goals it can be seen that the elements within the environment along with the elements of time and space are the opportunities offered by a situation. The projection of their status can relate to the goals that a user wants to achieve with these elements and the comprehension of their meaning depends on the interest of the involved users. These issues of awareness are examined in more detail in the following two sections.

#### 2.2.2.1 Situation Context Through the use of Physical Artefacts

Salvador et al. (1996) highlights five issues involved with interactive situations in collaborative systems. They consist of:

1) Dependency, relates to how dependent users are on each other;
2) Time, relates to the synchronicity of a situation;
3) Size, relates to the number of people involved in the task;
4) Location, relates to the physical location of the participants in the group; and
5) Timing, relates to the amount of planning that is required for interaction to occur

All of these issues can either increase or decrease opportunities for interaction and collaboration. For example the dependency can increase the opportunity if all users vital to achieving the goal are present but for every vital user that is absent the opportunity for collaboration decreases. Another example can be seen in relation to the size of the group and the synchronicity of the meeting. If there is a large group working synchronously on an object in a small workspace then the opportunity to contribute to a task is decreased.

Gutwin et al. (1995) highlighted four main areas of importance related to the awareness that a user has of the task and of the other users in the group. Although these awareness types were described with a focus on student awareness in educational groupware systems they are also applicable to other groupware systems. These four awareness types are social awareness, task awareness, concept awareness and workspace awareness. Social awareness is discussed in more detail in Section 2.2.3. Concept awareness is concerned with using information as a learning tool rather than as a tool for collaboration. The areas of interest at this level of context are the task awareness, discussed in the second part of this section, and workspace awareness types. Workspace awareness relates to being aware of what other users in the group have done, or are doing in order to complete the task. In workspace awareness the issues seen in Table 2.1 (Gutwin et al. 2001) are considered when looking at work in the present tense.

Table 2.1: Elements of workspace awareness relating to the present (Gutwin et al. 2001)

| Category | Element | Specific question |
|---|---|---|
| **Who** | Presence | Is anyone in the workspace? |
| | Identity | Who is participating? |
| | | Who is that? |
| | Authorship | Who is doing that? |
| **What** | Action | What are they doing? |
| | Intention | What action is that part of? |
| | Artifact | What objects are they working on? |
| **Where** | Location | Where are they working? |
| | Gaze | Where are they looking? |
| | View | Where can they see? |
| | Reach | Where can they reach? |

As well as having awareness of the workspace and workgroup in the present form it is also important to be aware of the state of the workspace and work group which relates to the past. The elements of awareness relating to the past can be seen in Table 2.2.

Table 2.2: Elements of workspace awareness relating to the past (Gutwin et al. 2001)

| Category | Element | Specific question |
|---|---|---|
| **How** | Action history | How did that operation happen? |
| | Artifact history | How did this artifact come to be in this state? |
| **When** | Event history | When did that event happen? |
| **Who (past)** | Presence history | Who was here, and when? |
| **Where (past)** | Location history | Where has a person been? |
| **What (past)** | Action history | What has a person been doing? |

This information will be required at some stage and in some combination during any collaborative work both in every day tasks and in tasks supported by some form of computerised support and will, to some extent, be impacted by elements of trust.

Workspace awareness is important to assess the opportunities that arise through collaborative interactions with other users and artefacts that advance task completion.

#### 2.2.2.2 Situation Context Through the use of Conceptual Artefacts

Opportunities not only arise through the presence of objects and users in a situation but also through the relationships that exist between the users. For example how much do users trust the technology and the behaviour of other users (Jones and Marsh 1997) and how aware are users of another user's knowledge (Gutwin et al. 1995) and interests (Endsley 1995).

Opportunities can be affected in a situation by the knowledge that users hold about other users that they are collaborating with. Through this mental model of other users a user can deduce opportunities that arise from information coming from them based on the information reliability. A user's perception of the reliability of information can be termed as the amount of trust they have in it or in the source that the information came from. In their paper on trust Jones and Marsh (1997) quoted Golembiewski and McConkie (1975) who said that:

> *…perhaps there is no single variable which so thoroughly influences interpersonal and group behaviour as does trust…*
>
> *Jones and Marsh 1997 (Sec. 2)*

The amount of unconditional trust of both users and technology that has to be adopted by users in collaborative systems is increased compared to conventional groupwork. The unconditional trust that has to be adopted for other users increases because in most collaborative systems that offer remote and synchronous working or asynchronous working in any location the only view available of that user is what the interface provides. This view will be limited in the number of diectic references that can be communicated (Dix 1994) and it is these references which can determine the validity of the information. The unconditional trust in technology increases due to the diminished performance of the collaborative technology through factors such as network speed. This will have the effect of reducing the speed in which feedback is received.

Task awareness is important in assessing the opportunities that are available in performing a task in order to achieve a goal. What is not included in these lists is the awareness of another user's interest, what do they want to do? Another important issue related to situation awareness is that individuals vary in their ability to acquire situation awareness and it is likely that given the same set of data two users will form two different opportunities (Endsley 1995). The main reason for this is due to the differences in interest that different users have. The interests that a user has in regards to situation, or workspace awareness are considered in the model of situation awareness in dynamic decision making (Figure 2.5) by Endsley (1995).

### 2.2.3 Understanding the Social Context

Level 1 of Mantovani's (1996) model examines the social context of the environment and has three concepts that are structure, action and history. Structure, or cultural models, looks at the cultural and social norms in the task environment and is the key element of context at level 1. The social context also examines the rationale behind the selection of the elements that make up the situation context such as the project management process undertaken to develop the collaborative technology (Stockman et al. 2000). Actions are the outcome of an evaluation of the current situation. They normally involve the formulation of goals that need to be achieved. History involves looking at how cultural norms change over time. Actions occur after the evaluation of the current situation and normally involve the development of a plan at level 2. Ngwenyama and Lyytinen (1997) sum up the interactions at this level of context in the following working definition:

> *We define groupwork as: a web of coordinated social actions, performed by the participants to achieve a joint outcome. The social actions of groupwork are situated within and normatively regulated by the organizational context.*
>
> *Ngwenyama and Lyytinen 1997 (pg.73)*

The social actions in this definition relate to Mantovani's 'action' concept and the organisational context relates to the 'structures' and 'history' that are present in the social context. The interactions with the collaborative system are determined by the allowable sequence of exchanges according to the social protocol that the participants are subjected to (Salvador et al. 1996). As in the situation context there are also important social awareness issues associated in the examination of social context (Gutwin et al. 1995). Most collaborative systems treat groups and individuals identically (Greenberg 1991) and do not address the differences in structure, action and history that influence group and individual behaviour. Although this refers to older products, it is still an issue in present collaborative systems.

Collaboration, in regard to social context, can be defined by the protocols in which it occurs (Salvador et al 1996). Salvador et al. suggest that there are five common elements that make up a social protocol which are:

1) Contention resolution, relates to the amount of contention required for a task to progress;
2) Meeting style, relates to the amount of participation that takes place from each participant;
3) Size, relates to the size of the group appropriate to achieve a goal;
4) Formality of address, refers to how formal, or structured, collaboration and communication has to be; and
5) Floor control, refers to who and how many participants have the ability to control the interaction.

Each of these elements is related to the structure that is present in a social context and will influence actions that occur in the environment. Each element will be influenced by the type of task that is being conducted. For example a discussion relating to adopting a new business plan will require a high-level of contention resolution whereas a task of scheduling a meeting using a shared calendar will require a low-level of contention resolution.

Ngwenyama and Lyytinen expand upon Mantovani's three concepts of social context by providing four categories of social action which consist of instrumental action, communicative action, discursive action and strategic action as seen in Table 2.3.

Table 2.3: Categories of social action and their characteristics (Ngwenyama and Lyytinen 1997),

| Category of action | Action orientation | Action constitutive resources |
|---|---|---|
| Instrumental | Transformation, Manipulation and Control of Objects | Technical knowledge, Tools |
| Communicative | Maintaining Understanding and Coordinating Action | Shared media for communication, Knowledge of language, shared norms, and the action situation |
| Discursive | Restoring Agreement and Conditions for Coordinated Action | Knowledge of rules of discourse and critical debate, Evaluation protocols, shared media for communication |
| Strategic | Influencing and Transforming the Behaviour of Others | Knowledge of the rules of process, and the opponent Items of exchange value, Shared media for communication |

Instrumental action focuses on the ability to achieve a goal through relevant knowledge of the tasks and artefacts available. In the framework by Mantovani instrumental action comes under the heading of both structure and action concepts. The structure is determined by having the relevant knowledge to achieve a goal that is determined by the action.

Communicative action focuses on maintaining mutual understanding among the group of participants. The basis of communicative action is that all of the participants understand the language being spoken and gain consensus on issues being raised. This understanding is influenced by knowledge of language and social norms and thus relates to the structure concept in Mantovani's framework.

Discursive action focuses on restoring communicative action when mutual understanding breaks down. Restoring mutual understanding revolves around the evaluation of goals, objectives and action-plans through argumentation and critical debate. In relation to Mantovani's framework restoring the mutual understanding means evaluating the structures and actions presenting a situation and changing them to restore understanding. The history concept is determined by the changes that occur through this evaluation.

Strategic action focuses on achieving an advantage over other individuals or groups. The aim of this is for an agent to influence and transform other participant’s goals to conform to their own. Strategic action is legitimate when its occurrence conforms to social norms, policies and the authority structure. In relation to Mantovani's framework, strategic action occurs within the concepts of structure and history. The structure refers to the rules of strategic action denoted by the organisation or society. History relates to the change in structure or action resulting from the strategic action.

In order for the concepts of social action to be effective it is important that individuals are aware that they exist and in what form. Gutwin et al. (1995) identify some issues of social awareness that assist in maintaining social action. These issues consist of:

1) What should I expect from other members of this group?;
2) How will I interact with this group?;
3) What role will I take in this group?; and
4) What roles will the other members of the group assume?

This is not an exhaustive list but is an indication of the issues that need to be raised. Other awareness issues arising from Ngwenyama and Lyytinen's work include the following:

1) How will I make other members goals and attitudes conform with my own?
2) What procedures do I have to follow to interact with this group?

A failure to recognise these issues of social context and the differences in social context for each participant or groups of participants increases the possibilities of a collaborative system failing. However, a real challenge exists in supporting these requirements in the design of technology (Ackerman 2000). Greenberg (1991) identifies six reasons as to why groupware systems have failed due to a failure in social context.

1) *A critical mass of system adopters may not be reached if too many people opt out of using the groupware product.* This occurred because of the associated overhead of learning the system and using its primitive interface. The structure presented by the groupware system did not match with the structure of its intended user;

2) Participants who cannot or will not use the technology face the danger of becoming second class citizens within their own group. All users refusing to use the groupware technology, for what ever reason, were discounted from any work processes occurring within the system. In this case the system was not used due to the users believing they did not have the skills necessary to use the system;
3) New people joining an established but evolving group must be able to use the system adeptly, otherwise cliques of expertise may evolve. It is very difficult for new members to establish themselves in a group that already has established procedures and a recognition of the history that has been experienced;
4) *Participants in a group may have quite different roles that are not recognised by the groupware product.* The established role hierarchy structure in a group is transferred into the groupware system but is not catered for by it. This causes an inability for a junior member of a group to take control away from a more senior member;
5) *There is often disparity between who does the work and who gets the benefits when using groupware.* This is as a result of the organisational hierarchy, it was found, in using shared calendars, that the workload for the whole group increased but the greatest benefit were usually to the managers; and
6) *Group needs evolve rapidly, not only from meeting to meeting but within the course of a meeting. The groupware must keep pace.* Groups change in their size and in the work that they do, this results in constantly changing structures for both groups and individuals.

A majority of these failures are caused by conflicting structures of either a group or an individual. These structures are often imposed upon the participants by the organisation or department that they work for and conflict with the structures the organisation or department introduce for the software use.

### 2.2.4 Discussion

Through this section collaborative systems have been examined in relation to issues arising at three contextual levels. It is accepted that there are three levels of context that are present in the use of collaborative systems (Mantovani 1996 and De Michelis et al.

1997) which consist of the system context, the situation context and the social context. At each level of Mantovani's framework there are three concepts that interact to form the contextual level. This section explored each of the concepts in relation to other relevant research to obtain a clear view of the issues associated with each concept. There are some fuzzy areas as to the distinctions between each level that is a result of many of the issues having implications on other contextual levels. The remainder of this section discusses what makes the study of collaborative system use so complex in relation to the study described in this chapter.

The increased complexity of studying collaborative system use compared to the use of single user systems is due to three main reasons which relate to the scope of study, communicating with other agents and the different utilities of collaborative systems.

*The scope of a study of collaborative system use*

It was seen from Mantovani (1996) and De Michelis et al. (1997) that studying collaborative systems means studying the social context, the situation context and the system context. Most studies of the use of single user systems are at the system context level. In collaborative systems it is important to consider not only how the user interacts with the system, but also how the user interacts with other users and how their behaviour is influenced by the society in which the are working.

*Communicating with other agents*

An aim of collaborative systems is to provide a substitute interface for face-to-face communication in group working. However, there are many issues that reduce the ability to communicate in collaborative systems. The most fundamental difference that has implications occurring at level 3 and that impact upon level 1 and level 2 is the lack of deictic references and physical presence available through collaborative systems. At level 2 this has implications on user awareness of actions and both the physical and conceptual artefacts being acted upon or communicated. It also has implications for a user to make judgements on the validity of information being presented. Not only are there problems in making participants aware of actions and objects it is also important to consider that even given the exact same state different participants are liable to have different perceptions of the opportunities that arise from it.

*Utilities of collaborative systems*

The study of collaborative systems is further complicated by the task of applying all of the above difficulties to different forms of collaborative system. Studying awareness issues in a synchronous and remote environment is very different to studying it in an asynchronous and co-located system.

## 2.3 Human Error and Collaborative Systems

Human error should be a major consideration in systems use and design. This is not just the case for safety critical systems such as those found in aviation systems but also in systems that are in common usage such as word processors, databases and communication systems. Safety critical systems have been a very popular forum for the examination and analysis of human error. In examples found in this area the consequence of an error is often blatantly obvious, for example a tower of flames half a mile high. The challenge is to discover the reasons why there was a tower of flames and to propose recommendations for prevention or limitation. In less critical systems high frequency human errors it can be harder not only to identify the reasons behind human error occurrence but also to identify that an error has even occurred as its consequences can often initially appear to be insignificant.

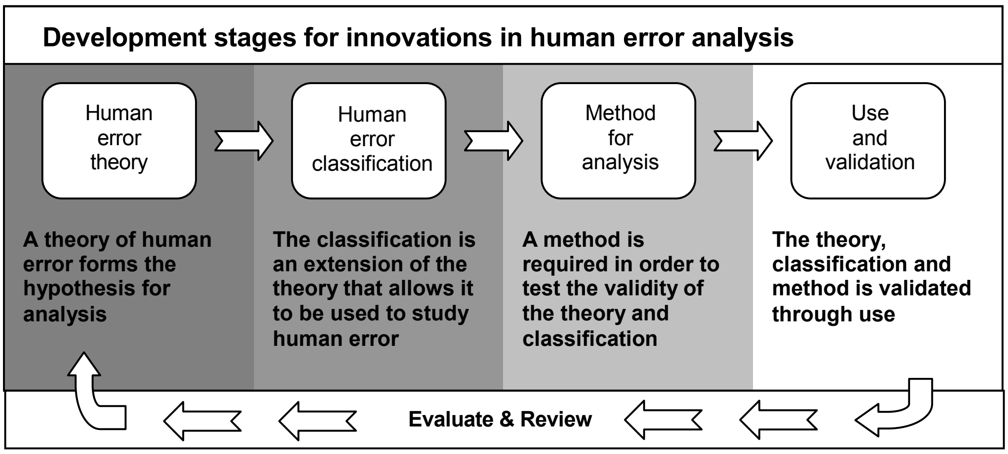

Figure 2.6: Development stages for innovations in human error analysis

Hollnagel (1993 pg. 203) implies a process of creating a means for analysing human error which is reflected in Figure 2.6. The human error theory forms the hypothesis that, through analysis, attempts are made to assess validity. In order to validate a theory it must be translated into a usable form such as a classification schema or taxonomy. The validity of a theory can also be assessed through its inclusion within an established methodology. If the theory can be translated into a taxonomy and a methodology then the theory can be said to be a valid one (Hollnagel 1993). The method is then tested to further validate the theory and to identify strong and weak aspects of the method. This model is reflected in the following sections of this chapter.

This section examines human error classifications and analysis methods in relation to their ability to be applied to the domain of collaborative systems. The first section describes different approaches to theories of human error. The second section describes how these theories are transformed into human error taxonomies. The third section describes human error analysis methods. The fourth section describes current application areas and focuses for human error research. The fifth section, discusses the complexities that collaborative systems add to human error analysis.

### 2.3.1 Theories of Human Error

Human error has been studied for over one hundred years as is described by Reason (1990). Reason gives a review of major studies of human error starting from James Sully's 1881 study of illusions and Freud's 1896 study of slips and moves on to the twentieth century looking at Wertheimer, Kohler and Koffka's work on the Gestalt tradition in 1912 and Bartlett's work on the notion of schema in 1932. All of these early human error studies were based on psychological and behavioural theories and not much has changed in more recent studies. Psychological and behavioural theories have proven to remain the basis for human error theory as seen in Wason and Johnson-Laird's 1972 work on imperfect rationality and Norman's 1981 work on action slips through to Reasons own work on skill, rule and knowledge based errors in 1990. Reason states, when introducing this review:

> *Since this is a psychological not a philosophical enquiry, I will focus upon those writers and early investigators who were directly concerned with the mental and behavioural aspects of error, specifically upon turn-of-the-century psychologists who sought to describe the variety of its forms and explain the processes underlying its production.*
>
> *Reason 1990 (pg. 20)*

Even though this extract states that only psychological and behavioural studies were included the people referenced are, without doubt, some of the most influential and major contributors to the development of human error theory to this date. The impact of these contributions is paramount to the continued reliance on psychological and behavioural studies to provide a basis for human error research. However, some would argue that human error is not an integral part of 'the study of behaviour and its contexts' and that a theory of human error is a 'special theory' in its own right (Senders and Moray 1991).

From their research on theories of human error Senders and Moray (1991) have identified two different approaches to a theory of human error. These are a theory of causes and a theory of reasons.

> *The* ***causal theory*** *would link chains of contingent events and the* ***reason theory*** *would deal with the justification of actions and the assignment of responsibility and blame.*
>
> *Senders and Moray 1991 (pg. 55, emphasis as original)*

These two approaches to human error theory provide an insight to the purpose of studying human error. The purpose of the causal theory is to discover what events led up to the human error possibly with the intent to prevent it from occurring again through the process of understanding why it occurred in the first place. The purpose of the reason theory is to discover whether the actions were justifiable and attributing elements of blame to the parties involved in the human error possibly with the intent of preventing it from occurring again by blaming the individuals involved.

More recent theories of human error (McCarthy et al. 1997 and Dekker et al. 1997) have adopted a broader theory of human error in their focus on the contextual elements that are involved in the occurrence of error.

> *Human error does not occur in a vacuum but is determined in part, and enabled largely, by the operational context in which it occurs.*
>
> *Dekker et al. 1997 (sec. 1.2)*

Although these recent approaches are broader they still focus on behaviour and psychology. It is important to note this recognition of the importance of context in studying human error as context naturally plays a major role in determining how an error will occur and this has also been recognised, to some degree, in early work such as Norman (1981). The more recent work places a larger emphasis on contextual information relating to human error.

In addition to this contextual work research has also been conducted in examining human error in organisations such as Woods et al. (1994) and Reason (1997). This work has been conducted in relation to how they occur in an organisational context, how they can be defended against and how they can be recovered from. Reason's (1997) theory examines organisational accidents directly from the error itself and how it manifests itself (Figure 2.7). The theory is not based on a theory of behaviour but is a theory based on the ability of human errors to breach organisational defence mechanisms. For an effective analysis this implies that there are defence mechanisms in place and that they can be identified. This is totally reasonable in an organisational context through rules and safety procedures but in collaborative systems it can be argued that there are rarely set defence mechanisms in existence and if they do exist, maybe in some subconscious form, they may not become apparent until after the erroneous incident.

Woods et al. (1994) describe a similar model to that of Reason's focusing on the organisational impact on human error. In this model the organisational context at the "blunt end" sets resources and constraints which impact and shape the attentional dynamics, knowledge and strategic factors, that make up the operational system as a cognitive system. This, in turn, affects the ability to deal with the problem demands present at the "sharp end".

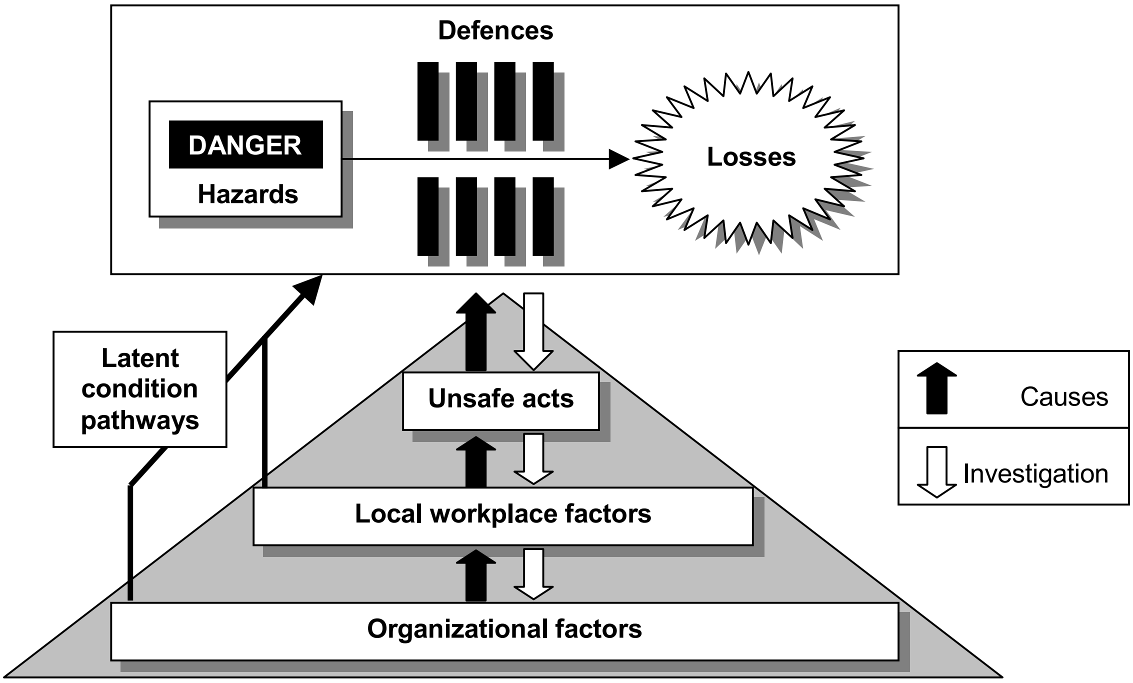


Figure 2.7: Development and investigation of an organisational accident (Reason 1997)

The research in this thesis is concerned with human error in collaborative environments. To date the error theories formulated over the past hundred or more years have only scratched the surface of discovering the impact of collaboration on human error outside of how it affects behaviour. The reason for this may be due to the complexity caused by the number of error mechanisms that are presented when multiple individuals are considered as confirmed by Senders and Moray:

> *There may be a small number of error mechanisms that affect any one individual; there may be an almost infinite number when many individuals are considered.*
>
> *Senders and Moray 1991(pg. 30)*

This 'almost infinite' number of error mechanisms is presented to those interested in human error when looked at from a behavioural or psychological perspective but are they still present when looked at from a social or collaborative perspective? If a social or collaborative focus is given to human error, and if the use of that approach does reduce the amount of error mechanisms, then a theory of collaborative human error is required to cater for collaborative environments.

This thesis argues that the psychological and behavioural approach and even the organisational approach may not be totally effective when looking at human error with a focus on collaborative environments. This does not imply that psychological and behavioural approaches are not effective for studying human error rather that an alternative focus on human error is required that will improve our understanding of human error in collaborative systems. From the examination in this section it can be said that the work on organisational accidents by Reason (1997) is the closest and most applicable theory for studying collaborative human error but is it really sufficient? This work by Reason and other work based upon more traditional theories are examined in more detail in the following sections of this chapter.

### 2.3.2 Taxonomies for Human Error

Over the last twenty years not much has changed in terms of the taxonomies used to examine human error mainly because they are derived from the same behaviour-based theories discussed above. Taxonomies such as the well known slip, lapse and mistake classification (Reason 1990), Norman's (1981) classification of action slips, Swain and Guttman's (1983) schematic error categories and, most notably, Reason's (1990) error categories based on human performance levels, are still used and referenced in human error research, such as Fields et al. (1995) and books such as Leveson (1995). This section examines what a taxonomy framework entails and examines the major taxonomies effecting recent human error research.

A human error taxonomy is a system of classification (Senders and Moray 1991) that organises and groups error types according to common properties. Senders and Moray state that the main reason why a taxonomy is required is because:

> *If we want a deep understanding of the nature, origins, and causes of human error, it is necessary to have an unambiguous classification scheme for describing the phenomena we are studying.*
>
> *Senders and Moray 1991 (pg. 82)*

Arising from this is the purpose of a taxonomy to assist in the extraction and analysis of data from accident and incident reports (Rassmussen 1987). The formation of a taxonomy of human error is a standard way to translate theories of human error into usable forms. The mechanisms that are used to classify errors are determined by the perspective that a theory examines human error from and by what the desired outcomes of applying that theory are. Senders and Moray (1991) and Reason (1990) state that there are three main types of mechanism that can be used to classify errors relating to behavioural, contextual and conceptual levels of classification. These mechanisms are:

1) *Phenomenological taxonomies (phenotypes).* Classify errors according to how they were directly observed for example omissions, intrusions and unnecessary repetitions;
2) *Cognitive mechanism taxonomies (genotypes).* Classify errors according to the stages of human information processing at which they occur for example attention failures and memory lapses; and
3) *Bias or deep-rooted tendency taxonomy.* Classify errors according to a person's deep-rooted beliefs and tendency towards 'tunnel vision'. A person may firmly believe that a path is the correct one to take and may ignore all over options.

A taxonomy does not fall into just one of these types but can have elements of each according to its underlying theory. A combination of these taxonomy types can be seen in the skill-rule-knowledge error taxonomy (Reason 1990) described later in this section. From examining the literature it is apparent that there are four common error classifications that form the basis of the majority of human error research being conducted. The four main taxonomies described in this section are:

1) Slip, lapse and mistake classification;
2) Classification of error phenotypes (Hollnagel 1993);
3) Performance level error classification (Reason 1990); and
4) General Failure Types (GFT) (Reason 1997)

In human error research it is commonly recognised that there are three main types of human error at a cognitive level that are slips, mistakes and lapses (Reason 1990, Norman 1981 and Hollnagel 1993). The distinctive features between a slip and a mistake are the intention and the plan.

- *Slip.* Failure in the execution of a task where the intention is correct;
- *Lapse.* Failure in the cognitive storage of task information where intention is correct
- *Mistake.* Failure in the selection of plans conducted for an action where the actions performed are correct.

A slip is defined as an error that results from failures at the execution stage of an action sequence. Slips are described and classified further in Norman's (1981) paper on action slips. This failure of execution can occur due to an unintended action being conducted or through the unintentional omission of an intended action, or a lapse. A lapse is classed as a mental slip such as memory recall failure. A mistake is defined as an error through an incorrect plan selection to achieve a desired outcome (Reason 1987). This classification of error is referred to in much human error research as a way to understand the importance of 'intention' in human error but, by itself, is not a useful tool as it fails to distinguish between manifestation and cause (Hollnagel 1993).

A common schematic error taxonomy was produced by Hollnagel (1993) which classifies errors that occur from observable task actions or phenotypes. The taxonomy consists of the elements seen in Figure 2.8. The taxonomy gives four main error types consisting of actions in the wrong place, actions at the wrong time, actions of the wrong type and actions not included in current plans. Within these four error types there are various simple phenotypes that have attached complex phenotypes. This taxonomy looks solely at observable behaviour and does not examine the underlying cognition relating to the cause of the error. By classifying observable actions it is possible to examine what is known as opposed to what can be speculated. When examining cognitive aspects assumptions have to be made regarding the causal characteristics of the human cognitive system.

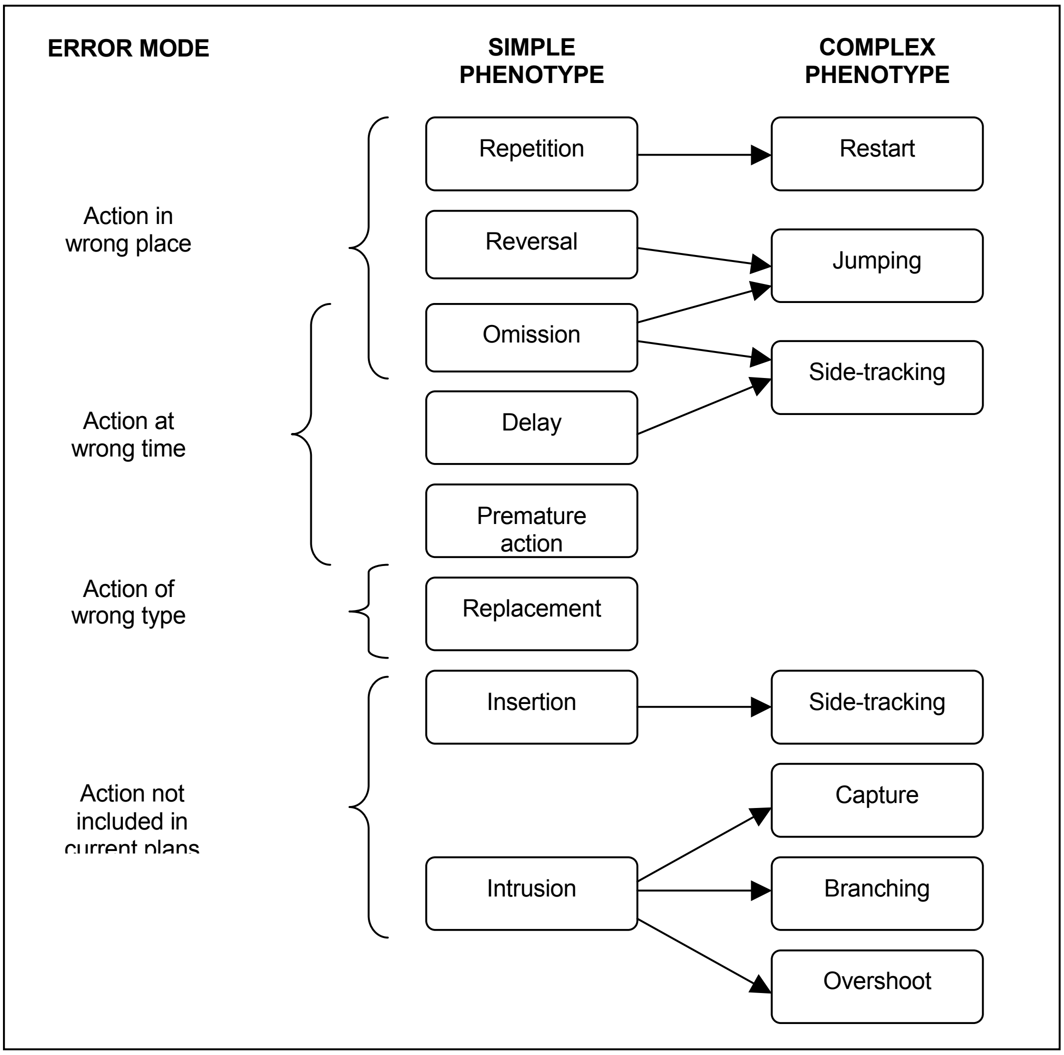


Figure 2.8: A taxonomy of phenotypes of erroneous actions (Hollnagel 1993, pg. 76)

Classifications of phenotypes, such as Hollnagel's, are useful in detecting errors when they do occur as they classify the observable consequences. However, they are of little value in providing causal explanations that allow correction and redesign that is provided by genotype error classifications. Phenotype error classifications are also limited in their focus on the particular error that occurred and ignore much of the contextual information relating to its occurrence.

The most commonly used taxonomy in current research on human error is the skill, rule and knowledge-based error taxonomy from Reason (1990). This taxonomy is based on the skill-rule-knowledge framework for human performance by Rasmussen in 1974 which has become the internationally accepted standard for the human reliability community (Reason 1990 and Sanderson and Harewood 1988). Likewise, Reason's taxonomy is approaching an equal level of recognition even though Senders and Moray (1991) have stated that a commonly accepted taxonomy was unlikely. The taxonomy assumes that human error occurs at one of three distinct performance levels. At the skill-based level slips and lapses can occur, at the rule-based level rule-based mistakes are made and at the knowledge-based level knowledge-based mistakes are made. This error classification is summarised in Table 2.4. The taxonomy combines many other human error taxonomies produced in previous research and attributes each error type according to the performance level it applies to.

Reason's skill-rule-knowledge taxonomy classifies the fundamental differences that appear in human errors. At some level it can be applied to most studies of human error but in some cases it can only be applied in part because a taxonomy is often specific to the domain and purpose of the human error analysis.

Table 2.4: Summarising the main headings for the failure modes at each of the three performance levels (Reason 1990, pg. 69)

| Skill-based performance | |
|---|---|
| *Inattention* | *Over attention* |
| Double-capture slips | Omissions |
| Omissions following interruptions | Repetitions |
| Reduced intentionality | Reversals |
| Perceptual confusions | |
| Interference errors | |
| **Rule-based performance** | |
| *First exceptions* | *Application of bad rules* |
| Countersigns and nonsigns | Encoding deficiencies |
| Information overload | Action deficiencies |
| Rule strength | Wrong rules |
| General rules | Inelegant rules |
| Redundancy | Inadvisable rules |
| Rigidity | |
| **Knowledge-based performance** | |
| *Selectivity* | *Problems with causality* |
| *Workspace limitations* | *Problems with complexity* |
| *Out of sight out of mind* | Problems with delayed feed-back |
| *Confirmation bias* | Insufficient consideration of processes in time |
| *Over confidence* | Difficulties with exponential developments |
| *Biased reviewing* | Thinking in causal series not causal nets |
| *Illusory correlation* | Thematic vagabonding |
| *Halo effect* | Encysting |

More recently taxonomies and frameworks have been expanded to incorporate contextual elements on a wider basis, most notably the work by McCarthy et al. (1997) on contextual aspects of human error and accountability, the work by Sarter and Woods (1995 and 1997) and Endsley (1995) on situation awareness and the work by Reason (1997) on organisational accidents.

McCarthy et al. (1997) developed a taxonomy for examining human error based upon elements of context, accountability and work practice. In this work four dimensions are proposed for vulnerable system contexts in specific work activities. These include:

1) *Explicit-Implicit dimension.* Concerned with the extent to which organisational and work processes are presented in forms that are available for external inspection;

2) *Global-Local dimension.* Concerned with the extent to which the work and its organisation are locally or globally structured;
3) *Stable-Transient dimension.* Concerned with the extent to which tasks and their allocation remain the same or change across situations; and
4) *Interdependent-independent dimension.* Concerned with the extent to which tasks are separable from one another or are contingent on one another.

These dimensions are applied to the accountability of an agent and the work practices involved in a vulnerable context situation. Table 2.5 gives the dimensions for common vulnerable contexts that arose through the analysis of case studies.

Table 2.5: Applicable dimensions for vulnerable suggested work contexts (McCarthy et al. 1997, pg, 761)

| Contexts | Accountability | Work practice |
|---|---|---|
| Collusion | Interdependent, implicit, stable, global | Local, implicit, interdependent, stable |
| Violation | Explicit, global, stable | Implicit, local, stable |
| Defence | Interdependent, global, stable | Interdependent, stable |
| Loss of control | Global, explicit | Global, independent |
| Buck passing/ diffusion of responsibility | Global, interdependent | Local, interdependent |
| Complacency | Local, implicit, independent, stable | Local, implicit, independent |

This taxonomy classifies the context of erroneous situations and assigns values relating to accountability and work practice to the context. In classifying errors in this way it is possible to assess the levels of accountability from the perspective of the individuals or social groups involved but it is not possible to gain an understanding of causality.

The final taxonomy discussed in this section is a scale upon which organisational human error can be examined. GFTs are used in the Tripod-Delta and MESH methods for analysing organisational accidents. Other similar taxonomies for organisational accidents include EPC (Error Producing Conditions) used in HEART (Human Error Assessment and Reduction Technique) and PIF's (Performance-Influencing Factors) used in the Influence Diagram Approach. The GFT taxonomy can be seen in Figure 2.9:

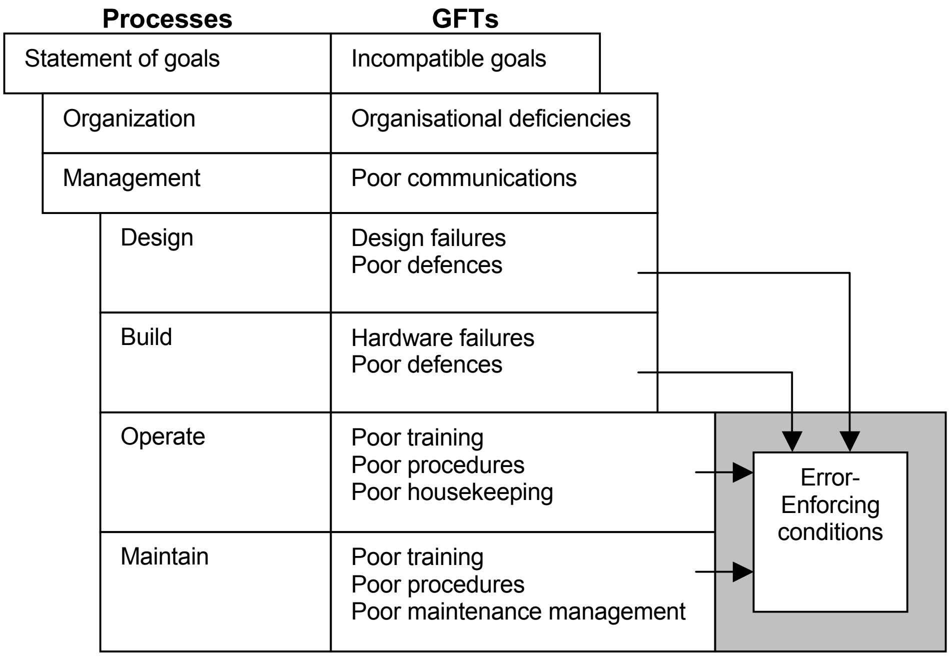


Figure 2.9: The relationship between the basic systemic processes and the general failure types, and the combined impact of the GFTs on the error-enforcing conditions Reason 1997 pg. 136).

The diagram in Figure 2.8 shows the relationship between the basic systemic processes to the general failure types. There are six processes identified as being prone to error which are the statement of goals, organisation, management, design, build, operate and maintain. The GFTs give classifications of how these processes may fail which can be marked according to severity based on checklist scores. This taxonomy, and others like it, are good taxonomic scales to examine organisational human error but lack the ability to provide information on how these organisational factors affect human errors from the perspective of small groups and individuals.

The taxonomies examined in this section are well established methods for examining human errors at both the cognitive and organisational levels of system use but there is little support for errors occurring between these two extremes and the relationships influencing cause and effect that may occur between them. This is especially the case when examining the human error on the scale of small collaborating groups that float somewhere between the cognitive and organisational levels. For example there is no support for deficiencies in situation and workspace awareness, misunderstandings of meaning or conflicts of opinions or beliefs. There is also little support for examining the impact that organisational or individual factors have on human errors occurring in these collaborating groups.

### 2.3.3 Methods for Human Error Analysis

Human error analysis has been conducted from two perspectives over the last twenty years. The largest established body of research (Norman 1981 and Reason 1990) has examined human error from the perspective of human cognition (Viller et al. 1999). The second perspective of human error, emerging more recently, proposes that human error does not occur in isolation but is influenced, in part, by the context in which it occurs. This second perspective of human error came about due to the realisation that ignoring the context in which human error occurs prevents a complete understanding of its occurrence. McCarthy et al. (1997) affirm this position:

> *There is growing recognition that identifying human error as the ultimate cause of a system failure is of limited use unless the context in which the error was elicited is well understood.*
>
> *McCarthy et al. 1997 (pg. 735)*

The emergence of these two human error perspectives has produced two different forms of human error methodology of which the contextual method is currently the more fashionable and in the case of studying human error in collaborative systems is more applicable. When examining these methods they can be examined from two perspectives; how data about human error is gathered and how human error is analysed. Even though these different approaches exist the general method options adopted to analyse human error remain the same for all types. This section explores first the options available for gathering human error data and then the choice of either a qualitative or quantitative analysis.

#### 2.3.3.1 Gathering Data on Human Error

Before any analysis of human error can be completed reliable data has to be gathered that can be analysed. The methods adopted to gather data on human errors have been listed by Reason (1997) and are as follows:

1) Naturalistic methods or ‘corpus gathering’;
2) Questionnaire studies;
3) Laboratory studies;
4) Simulator studies; and
5) Case studies.

This section examines these methods in turn with reference to research that utilises each approach. The examination aims to illustrate appropriate methods for different applications of human error study. Applications of human error research are described in more detail in the following section.

Naturalistic methods or ‘corpus gathering’ refers to the collection of everyday human errors. Perhaps the most famous example of this can be found in Norman’s (1981) work on the categorisation of action slips. In this approach large collections of error examples are gathered in order to provide a means of effective classification and to provide a basis for understanding human error. These examples can both be personal experiences of the researcher or examples heard or observed happening to someone else. The approach is suited to the examination of human errors that occur frequently. If a specific type of error is being examined then this approach is not suitable because the particular error type will occur too infrequently to provide enough data for a meaningful analysis.

Questionnaire studies are a common method of collecting information about human errors in organisational settings. After a human error occurs the individual making the error will complete a questionnaire requesting details about its occurrence. For example, to rate whether the error was a slip, mistake or lapse or to rate the seriousness of the consequences arising from the error.

Laboratory studies are, as the name suggests, studies of human error in a controlled condition environment and can provide depth and validity to a study of human errors. However, studying human errors in controlled environments contains all of the advantages and disadvantages connected with such an approach such as how the conditions affect the way in which an error occurs.

Simulator studies are when the real world is modelled, commonly by building a computer simulation, producing an environment where the consequences resulting from a human error can be controlled or eliminated. This approach is commonly used to test aeronautical systems where the consequences of a human error can be life threatening. There are very few examples of simulator studies reported in the academic research literature mainly due to the cost of building simulations which are sufficiently realistic to provide valid results.

Case studies are well documented examples of human error, that normally have resulted in some form of catastrophe. An analysis is possible through the examination of accident and incident reports created by investigators. Case studies are perhaps the most popular tool for gathering data on human error as seen in Chambers et al. (1999), McCarthy et al. (1997), Sarter and Woods (1995) and Beynon-Davies (1999). A reason why case studies are such a popular method for gathering information is given by Reason (1990):

> *Where sufficient evidence is available regarding both the antecedent and the prevailing circumstances of a particular event or accident, we are able to study the interaction of the various causal factors over an extended time scale in a way that would be difficult to achieve by other means.*
>
> *Reason 1990 (pg. 16)*

An extended time scale allows the study of erroneous events that occur over hours and even days. Another reason why case studies are so popular is because of the high profile nature of many of the accidents reported in case studies. However, cases studies are also available for low impact human errors such as those seen in Chambers et al. (1999).

However, the use of case studies also has its problems. Accident and incident reports are primarily aimed at attributing blame for an event and there are questions that have to be asked about bias, accuracy and completeness.

#### 2.3.3.2 Analysing Data on Human Error

It was identified in the section on human error taxonomies that there is support for analysing human error from the perspective of the individual and from the perspective of the organisation but there is little support for group collaboration that occur between them.

In addition to the differences between contextual and behavioural studies the distinction also exists, that is common in all psychological studies, between a quantitative and a qualitative analysis. The selection of qualitative or quantitative study depends upon the goals of the analysis and the domain in which the analysis is being conducted. For example an analysis with the aim of predicting the potential of human error through evaluating the frequency of their occurrence requires a quantitative approach in a domain where human error is a common occurrence. Alternatively an analysis with the aim of understanding the causal chain of events that contribute to human error requires a more qualitative approach.

This section identifies a selection of analysis methods that either focus on individual human errors or organisational errors and the qualitative or quantitative nature the method adopts.

A majority of the traditionally accepted techniques have been quantitative and individual based and have the aim of predicting when human error is likely to occur. Such techniques include THERP (Technique for Human Error Rate Prediction), OATS (Operator Action Trees), TESEO (Tecnica Empirica Stima Errori Operatori) and the Confusion Matrix. Most of the quantitative approaches involve producing a detailed task analysis model of the possible interactions with an interface and then apply some form of probability matrix to assess the likelihood of a task being conducted incorrectly. A domain expert through a process of probability estimation normally assigns this probability measure. Through the process of conducting such studies an understanding of human error is gained through conducting the task modelling and an analysis is produced through assessing probabilities. The main problem with this approach is that the analysis is their accuracy. In many cases a very poor accuracy ratio is achieved compared to the targeted 90% (Reason 1990). The reasons for this lack of accuracy can be attributed to the fact that not all possible task sequences can be predicted and the fact that probabilities are estimations based on previous events. However, as of yet no better solution has been proposed to resolve this lack of accuracy.

Theories examining the wider organisational aspects of error management include MESH, Tripod-Delta, HEART (Reason 1997) and the Contextual Control Method (COCOM) (Hollnagel 1993). Not all of these methods encompass all aspects of human error from individual user actions to the wider organisational contribution and many are designed for single, specific application domains such as oil exploration, aircraft maintenance and railway operations. These theories utilise taxonomies such as GFT, EPC and PIF described in the previous section of this chapter.

As yet there are very few established and recognised methods for qualitative analysis though it is recognised as possibly a much more useful approach compared to a quantitative approach (Hollnagel 1993 pg. 93). Much current research is involved in studying contextual relationships in human error to form a basis for such a method. Such methods include work on measuring accountability by McCarthy et al. (1997), work on the diagrammatic representation of human error such as Love and Johnson (1997) and organisational or socio-technical approaches to human error such as Baxter et al. (1998), McCarthy et al. (1998) and Reason (1997). The qualitative work aims to gain understandings of human error and how they occur through the examination and comparison of human error examples.

From examining these methods, regardless of whether they are qualitative, quantitative, behaviour based or organisation based, there is a commonality in that they all follow similar procedures. These common procedures can be seen in Table 2.6.

Table 2.6: Common procedures in human error analysis methods

| | Stage | Description |
|---|---|---|
| **Stage 1** | Knowledge acquisition | Gathering knowledge relating to the real or potential occurrence of human error. Achieved through interviews, accident/ incident reports, observations and experimentation. |
| **Stage 2** | Task analysis | Structuring the knowledge into task sequences, models of cognition or models of context |
| **Stage 3** | Identification of human error | Identifying how and where human errors occur in a task sequence. |
| **Stage 4** | Analysis of human error | Deriving useful conclusions from a detailed examination of the human errors and the context in which they occur |

These stages may vary in terms of the approaches adopted to complete them but the fundamental aims remain the same. Specific examples can be seen in THEA (Fields et al 1997) and COCOM (Hollnagel 1983).

### 2.3.4 Application Areas for Analysis Results

In the previous sections theories of human error, taxonomies and analysis methods have been examined. The results of a human error analysis can be used for different purposes. The application of analysis results examined in this chapter include the following

1) Reducing the potential risk of human error;
2) Understanding the occurrence of human error through identifying their causes, reasons and effects; and
3) Improving the presentation of human error reporting.

The following sections explore how each of these applications can be achieved.

#### 2.3.4.1 Reducing the Potential for Human Error Occurring

The aim of examining human error is not to eliminate them as this is an impossible task (Fields et al. 1995). The aim is to classify human errors, examine their causes, ease their detection, reduce the criticality of their consequences and ease of recovery (Rizzo et al. 1996). Five methods have been proposed by Sarter and Woods (1995) to handle and defend against complex error formations.

1) The first is to simply reduce the number and complexity of modes present in the system;
2) The second solution is to support the increased knowledge requirements created by the increased automation through new approaches to training;
3) The third solution is to develop new forms of mode awareness through redesigns of the interface;
4) The fourth solution is to implement a “forcing function” which prevents the behaviour from continuing until the problem has been corrected. This can be achieved using a number of methods such as predicting the users intention and only allowing valid interactions to achieve the aim and preventing all unrelated actions; and
5) The final solution is supervisory control so that consent has to be given before an action is activated.

The first solution may not be desirable for many reasons such as reducing the generic nature of a piece of software and thus making it more specialised. The second solution has the problem that the users will be trained to use the system in a number of contexts and will become strongly conditioned to operating within these contexts. Occasionally the users will be required to use the system in new contexts that go beyond these established and learnt routines which may result in factors that require reference to a new knowledge resource. The third solution requires the system to provide better indications of which mode it is in and how future actions affect its state and to provide better recovery from mode misassessments when they do occur. This could be done through visual cues on the display, audio cues or through a history list. There are a number of problems with forcing functions such as there has to be only one legal action or strategy for each intention and the system has to be accurate at predicting intentions. The final solution can create problems in imposing unnecessary burdens on to the users and a risk of the task becoming mindless and automatic.

#### 2.3.4.2 Understanding the Occurrence of Human Error

A further aim of human error analysis is to gain an understanding of the causes, reasons and effects of a human error. Through this understanding lessons can be learnt that can help to reduce the likelihood of a similar errors reoccurring and reduce the criticality of the consequences should it reoccur.

It was stated earlier that there are both reasons and causes for a human error where a reason is the justification of actions and the assignment of blame and cause relates to the linking of contingent events. Reason (1997) states that it is more productive to focus on causes as opposed to reasons that are the main focus of human error methods. By focusing on causes it is possible to understand the links between events and situations that lead up to an error. This means that in future interactions these links can be broken or safeguards can be established (as described in the previous section) reducing the likelihood of a similar error reoccurring.

Understanding the consequences of an error enables safeguards to be implemented reducing the criticality of the consequences and aiding recovery. For example, manual recovery methods such as implementing “undo” features to enable a user to reverse the consequences of the error or automated recovery methods such as ABS brakes in motorcars to reduce the consequences of braking too hard in slippery conditions. These recovery mechanisms can also act to reduce the risk involved in interacting with the system as proposed in Dix et al. (1996) enabling users to be bolder in their actions. The implementation of ABS brakes may increase the confidence of the driver in the cars ability to control a skid enabling them to feel safer when driving at faster speeds. This phenomenon can also be seen termed as risk homeostasis in Hollnagel (1993).

Understanding the consequences of an error also aids in our ability to assess the risks involved in choosing one option over another in a decision making process. As most organisations are attempting to improve productivity and efficiency compromises are often made in their decision-making and compromises can often lead to increased levels of risk. Understanding the consequences of our actions enables us to make more accurate risk assessments.

#### 2.3.4.3 Improving the Presentation Human Error Reporting

Improving the presentation of human error reports leads to an improvement in the understanding of human error. The presentation of accident and incident reports (Johnson 1999a) is a vital aspect of human error analysis. The exploration of different ways of visualising accidents, incidents or other human error representing the impact of time (Johnson 1998) and the context in which they occurred can expose vital information that was previously hidden. This can be achieved by increasing the ability to compare accidents and incidents from different perspectives and by increasing the availability for the results of a human error to be seen and understood by a wider range of people.

The most popular method of improving the presentation of error reporting is to model the events in a diagrammatic form such as Consequence Analysis Evidence (CAE) diagrams, Cause, Consequence Diagrams (CCD), Fault Trees and Petri Nets (Love and Johnson 1997). Research is also being conducted to examine the effectiveness of dynamic, 3-dimensional representations of an error and the environment in which it occurred. Internet technology such as VRML, QuicktimeVR and Java3D is being examined in relation to how it can be utilised as a means for presenting these models to aid in the visualisation and navigating of lengthy incident and accident reports (Johnson 1999a).

However the information is presented there still needs to be a mechanism for collating the data that provides a structure upon which an effective presentation form can be based. Currently this structure is lacking especially in terms of presenting a holistic view of erroneous occurrences and especially when looking at ways to present this data using Internet technology.

### 2.3.5 Discussion

This section has examined the domain of human error from the perspective of theories, taxonomies, methods and application areas for their results. The chapter began with a description of how approaches to human error analysis evolve through the creation of a theory and taxonomy through to the applications possible from the results of an analysis methodology. This process has been reflected in the structure of this section.

What can be seen from this examination of human errors is the complexity of understanding their occurrence, their analysis and methods to adopt to reduce their risk and impact. The complexities of studying human error in identified in this section are summarised in the following list originating from Woods et al. (1994):

1) Some of the contributors are latent, lying in wait for other triggering or potentiating factors;
2) The human performance in question involves a distributed system of interacting people and organisational elements;
3) The same factors govern the expression of both expertise and error;
4) The context in which incidents evolve plays a major role in human performance;
5) People at the organisational level create dilemmas and shape trade-offs among competing goals for those tackling the problem; and
6) The way technology is deployed shapes human performance, creating the potential for new forms of error and failure.

This list of complexities of studying human error includes the impact of organisations and collaboration on the occurrence and effect of human error as well as single user factors. Many of these complexities are not catered for effectively by current behaviour-based human error methodologies which indicates that there is still much work to do to improve the understanding of human error and how it can be analysed.

Important factors have emerged relating to considerations that theories and methodologies for human error analysis should address. To summarise an effective approach to human error analysis should address:

- Organisational factors,
- Situation factors,
- User actions,
- Intention,
- Error latency,
- Cause/ effect chains,
- Defences against human error,
- Knowledge based, rule based and skill based behaviour,
- Cause, effect, detection, consequences, recovery,
- Contribution to error, technology, human performance, organisation, collaboration.

All of these factors are catered for in current human error analysis but not all these factors are addressed by all approaches or in a collaborative system environment as has been stated by Sarter and Woods (1995).

> *…the human error, cognitive engineering, and human-computer interaction communities have barely begun to study the relevant issues to provide the necessary research base to drive or support practical advice to designers.*
>
> *Sarter and Woods 1995 (pg. 15)*

There are also important questions deriving from collaborative systems that are not addressed by a majority of current approaches. These include:

- How can the impact that both spatially and temporally distributed behaviour has on human error occurrence be addressed in human error analysis?;
- How can concepts within social context, situation context and local interactions and the relationships between them be addressed in a human error analysis approach?;
- How can social awareness, situation awareness, workspace awareness, user awareness and the relationships existing between them be addressed in an approach to human error analysis?;

- How can the impact of spatially and temporally distributed group dynamics addressed in human error analysis?; and
- To what extent do collaborative systems create new types of human error that are specific to these environments.

These questions are the fundamental high-level issues that need to be addressed when examining human error in collaborative systems and are addressed in the following chapters of this thesis.

## 2.4 Summary

This chapter provides an overview of the literature survey conducted in this research. The chapter began by discussing the need to consider human errors in collaborative systems. The chapter then went on to describe the scope of collaborative systems and the potential complexities they add to a human error analysis. Finally, the chapter described current approaches to analysing human error and their ability to address the added complexities found in collaborative systems.

The study of collaborative systems is much more complex than that of traditional single user systems. This is because of the temporal and spatial distribution of contributing objects and actors and the need to consider a much larger range of issues from social context, through to situation context, through to local interactions.

Theories of human error have traditionally been based on theories of behaviour and cognition and thus influence the taxonomy, the method and the applications deriving from it. This thesis describes a number of complexities of human error analysis that are not tackled sufficiently by current methods. The following chapters of this thesis examine whether a new approach to human error can be adopted to analyse human error in collaborative systems and whether this new approach provides answers to the questions raised by the complexities experienced by current methods.

# Chapter 3

## 3 Towards a Model of Human Error in Collaborative Systems

In the previous chapter concepts involving human error and collaborative systems were introduced and discussed. From this research a clear understanding can be gained of the issues and complexities of studying human error in these team-based environments. Current human error theories, taxonomies and methods are unable to sufficiently support these environments. This leads to the focus of the research described in this thesis relating to the examination of a new approach to understanding human error that is described in this chapter. With the growth in the use of collaborative technology it is of increasing importance to gain an understanding of how human error can occur in these environments.

From the previous chapter it was seen that studying human error in team environments introduces a number of complex issues that are not dealt with effectively in current human error classifications and analysis techniques. The main complicating factor is the introduction of multiple agents in the interaction process. It is of little use to analyse a situation simply by saying an incorrect task schema has been carried out. Identifying the effects of other agents in causing this incorrect task schema and the effects it has on other agents will result in a much richer and more productive analysis. The main factors arising from introducing multiple agents are as follows:

1) The introduction of issues of social context, situation context as well as interactions with the interface. This can be seen in the framework for collaborative environments by Mantovani (1996);
2) The introduction of issues of awareness. This includes an agent's awareness of issues relating to a different agents social context (Gutwin and Greenberg 1995) and situation context (Gutwin and Greenberg 1996);

3) The introduction of CSCW issues such as control and feedback, diectic references, understanding, direct communication and feedthrough (Dix 1994) that are inherent in current groupware systems;
4) The introduction of issues of preparation time, synchronicity, group size location and information dependency present in interactive situations (Salvador et al. 1996); and
5) The introduction of issues of floor control, contention resolution, meeting style and formality present in interactive social protocols (Salvador et al. 1996)

This chapter addresses the occurrence of human error in collaborative systems. This is achieved by mapping human errors into Mantovani's and Dix's collaborative frameworks in relation to a test scenario (Trepess and Stockman 1999) and real life examples of human error. The last four factors are discussed in relation to how they can be applied to a model of collaborative human error.

The purpose of this chapter is to explore how human errors occur, using Reason's (1990) human error classification, in collaborative systems and to identify important issues that are the focus on collaboration. This study addresses the first research sub-goal of examining the occurrence of human error in collaborative systems and identifying the issues involved in such an approach. From this study a model of collaborative human error is described which will describe how this sub-goal has been achieved.

In Section 3.1 of this chapter human error is examined in relation to the impact that the issues of collaborative systems have on a collaborative focus on human error. In Section 3.2 human error is examined in relation to each level of the framework and to other issues of CSCW, listed above, that are relevant to each level. Section 3.3 gives a brief examination into two real examples where collaboration plays a role in the occurrence of human error. Finally, Section 3.4 presents a model of collaborative human error based on three levels of context.

## 3.1 Considerations for a Model of Collaborative Human Error

The section describes where the collaborative issues identified in Chapter 2 apply to a contextual, three level approach to collaborative human error. From the examination of collaborative systems conducted in Chapter 2 it was seen that there are many issues involved in collaborative systems that need to be considered when exploring collaborative human error. In this section a selection of these issues are discussed in relation to how they can assist in the examination of a contextually based model of collaborative human error. This is done by examining level 1, level 2 and level 3 of Mantovani's collaborative framework.

### 3.1.1 Collaborative Issues of Social Context

At the level of social context the focus is on the social norms, social history and high-level goals present in a collaborative situation. The collaborative issues that can be applied at this level are the interactive social protocol (Salvador et al 1996) and the issues of social awareness (Gutwin and Greenberg 1995).

The interactive social protocol introduces issues of contention resolution, meeting style, group size, formality of address and floor control. All of these issues have one common theme which is they all relate to different social 'styles' or structures that have a direct relationship to collaborative systems. This means structures that facilitate collaboration rather than higher level issues, such as national legislation, that have an indirect effect on the collaboration. The structures provided by interactive social protocols can be applied to the collaborative human error model by implying a sub-level exists at this level of social context that provides a distinction between direct and indirect effects of social context on collaboration.

The issues of social awareness provide information about what users should expect from other users in a group, how they will interact with the group, the role that a user will take in this group and the roles that other users of the group assume. This is not an exhaustive list. In a similar way to interactive social protocols these issues of awareness are directly related to the collaboration but are more focused on the information a user needs about other members of the group in order to interact with them. These issues apply to the model of collaborative human error in the way the collaboration requires the users to form a structure of how they will work with each other. This may be a structure that assigns roles to each user and the relationships between them.

The elements of social context described here can aid in the analysis of collaborative human error by providing an understanding of what information is required for analysis at this level.

### 3.1.2 Collaborative Issues of Situation Context

At the level of situation context the focus is on opportunities, interests and plans that are offered within a situation. The collaborative issues that can be applied to this level are interactive situation models (Salvador et al. 1996) and the elements of workspace awareness (Gutwin et al. 2001).

The elements of interactive situations consist of dependency on information, synchronicity, group size, location and planning. These elements directly relate to the opportunities present in a situation and, to some extent, to plans that are formulated.

The issues of workspace awareness include elements relating to the opportunities, interests and plans of users in a group and how they affect other users. For example, awareness of where a user is working, what they are doing, what objects they are using and what they can see. By applying this to the level of situation context in collaborative human error it is possible to build up a complete picture of the opportunities, interest and plans utilised by each user.

The elements of situation context described here can aid in the analysis of collaborative human error by providing an understanding of what information is required for analysis at this level.

### 3.1.3 Collaborative Issues of Local Interactions

Local interactions with collaborative systems will occur in much the same way as with a conventional single user system in that the users will make plans to interact with the environment based on the tools that are available. The difference, at this level, is that the system responses to user actions will be much more unpredictable. This is because a user action will prompt a response from both the system itself and the other users of the group. System responses can be fairly predictable but the responses of other users are mostly unpredictable and will depend on factors at the levels of social and situation context.

## 3.2 Human Error in a Collaborative Context

In the following sections this chapter analyses how a traditional human error outlook can be applied to Mantovani's CSCW framework. This is done by progressing through the three levels of the framework and looking at how the error classifications apply to the different contexts and in relation to error type, cause, consequence and recovery. For the purpose of this chapter Mantovani's framework is looked at from a bottom up perspective starting with the level of local interactions and ending with the level of social context. The reason for this is because interactions occur with the interface of a computer system and this is where, according to traditional human error theories, errors occur. The effects of these interactions will then have repercussions on the levels above. The other issues from Gutwin and Greenberg, Dix and Salvador et al. listed earlier are drawn upon, where relevant, as each level is discussed.

### 3.2.1 Human Error at the Level of Local Interactions

The concepts occurring at this level of the framework consist of tools, users and tasks. The tool concept refers to objects that are created to serve a purpose. The user concept refers to the agents that will use the tools and the task concept refers to the dynamic actions between the user and the tool.

Most erroneous actions physically occur at the level of local interactions with an interface but often their causes and consequences will only appear in higher levels of the model. Due to the fact that this lower level of local working conditions is where all of the low-level operations occur erroneous actions at this level take an active failure pathway. These take the form of both mistakes and slips in much the same way as can be found in single user interfaces. However, the consequences of these errors may, or may not, affect the whole group. This leads to two forms of erroneous consequence in collaborative systems being present which are errors with:

1) Single user consequences (SUC); and errors with
2) Multiple user consequences (MUC).

From looking at Dix's framework for CSCW described in Chapter 2 it can be seen that there are three main areas relating to CSCW artefacts which are understanding and direct communication, control and feedback and feedthrough. These all occur in relation to tools, users and tasks. Each of these is prone to different forms of erroneous actions described below.

Erroneous actions in the area of understanding are influenced by what and how information about a task is communicated using the tools provided. At this level the actor's assumption is that almost everything that is communicated will be understood by the other actors in the group. Due to this assumption, potential erroneous actions with MUC's may start from this level but often will not become erroneous until put into the context of the attributes of the other members of the group. The lack of visual or verbal deixis, through deficiencies in the tool, can also confuse an actor's understanding of the system. Deixis and back channels have a great influence in communication in the way that they can add meaning to statements with hand movements, expressions and tone of voice. With the lack of deictic references and back channels that are available in CSCW, users have to be more explicit in their communication and it is inevitable that erroneous actions in the form of false sensations, misperceptions or inferential errors will occur.

Feedback is a vital area for error detection, prevention and recovery but in CSCW this feedback comes from two sources: the computer interface and communication with other group members either through the machine or through other means. It is important that the users remember that they are not only communicating with a machine that has definite rules about what is the right or wrong procedure and which will often inform the user if an action is inappropriate for a certain context. In a single user system the user builds up a mental picture of the system and its functionality and thus has an idea of how to successfully interact with that system and what feedback to expect from it. However, in CSCW, the user has to build up a mental model, not just of the system, but also of the behaviour of other agents in the group. Users of CSCW systems must be able to interpret and understand feedback received from other members of the group and in turn give feedback that will be easily understood. Most systems do not offer protection or warnings about messages which may be wrong, inappropriate or misleading to other users.

Systems that facilitate feedthrough allow communication to be conducted through the tools themselves. Dix (1994) gives the example of the difference between two people carrying a piano and two people carrying a mattress. Two people carrying a piano will receive feedback through the actual piano in the form of push and pull forces. Two people carrying a mattress will get a dampened feedback as the push and pull forces will be absorbed in the mattress and thus the task requires a greater amount of communication and mutual understanding.

The probability that erroneous actions at this level will have consequences at higher levels of the model will depend greatly on the synchronicity of the CSCW artefact. For example if a slip occurs in an asynchronous system and is detected then it can be recovered before being transmitted to other actors in the group resulting in SUC's. In a synchronous CSCW artefact errors will be irreversibly transmitted resulting in MUC's and will often require actions at higher levels of the framework to recover from them. In an asynchronous system the task operators will be the same as for a single user interface. However, in a synchronous system more care needs to be taken in the choice of operators as each input is communicated to the recipients. A lack of synchronicity, here, can act as a defence against erroneous actions having consequences at higher levels.

Errors with SUC's and MUC's both need to be recovered from through the higher levels of the framework as they both cause diversions from the main goal and are unlikely to be detected until these higher levels are considered. The difference between the two is that SUC's, unlike MUC's, do not require communication and negotiation to be recovered from. As it was mentioned earlier potential errors may start from level 3 but do not actually become erroneous until placed in a situation context at level 2.

### 3.2.2 Human Error at the Level of Situation Context

The concepts occurring at the level of situation context consist of opportunities, interests and goals. Opportunities relate to the ability, provided by a situation, to perform a task. Interest relates to a task that a user wishes to achieve. Goals relate to a plan that can be achieved through the correct opportunity and interest being present.

At this level of Mantovani's framework not all eight error types can occur but all can have an influence. The types of errors that will occur at this level and at level 1 follow a latent failure pathway and take the form of mistakes because the erroneous actions are caused through debate, decision-making and the distortion of information.

Opportunities arise through the examination of the entities that exist in the current local environment. These entities can include people, places, tools, information etc. Due to the nature of CSCW each actor in the group is likely to have different opportunities available to them unlike conventional face-to-face group work where the opportunities are similar to all members of the group. A deviance in opportunities available to a group of actors can affect the group's ability to achieve the common goal. An example can be seen in Figure 3.1.

> A goal of Actor X and his organisation, in New York, may be to get a proposal accepted by the client, Actor Y who lives in the UK, by the end of the day. He has the perfect opportunity to present this new concept to the rest of the group in the sense that all the right people are taking part in the meeting, he has all the information that is required, he has just had his lunch and he is ready to impress Actor Y with his ideas. However, Actor Y is currently going home on the train as the time in the UK is 6.00 p.m. and does not have the information that is required to analyse the proposal.

Figure 3.1: Collaborative human error scenario (Part 1)

As the opportunity was not right for Actor Y then Actor X's goal of getting his proposal accepted that day is not possible and thus the situation becomes a conflict of interests. The consequences of this error cannot be reversed and a method of recovery has to be devised in order to limit the seriousness of the consequences. This will involve deriving new goals at level 1 and new plans at level 2 for achieving them.

People see opportunities only if they are highlighted by their interests or are pointed out by other actors. Conflicts of interest can be seen in the following extension to the scenario in Figure 3.2.

> Actor Y has found the information that was needed, buried deep in his brief case. At the time of the meeting he is riding the train home thinking about a romantic dinner for two which was planned for that evening and is more concerned with what to wear or where to go than with Actor X's inspired idea.

Figure 3.2: Collaborative human error scenario (Part 2)

In this example the opportunity for Actor X and Actor Y were both appropriate but their priority of interests were different. Actor X had just finished lunch and was ready for an afternoon's work whereas Actor Y was just winding down after a hard days work and the interest priority was to prepare for the evening out.

The errors at this level can all come under the title of planning conflicts as the resultant factor is the failure to achieve a plan or an incorrect plan being adopted. These failures can result from:

- A lack of interest, inappropriate interest priorities or a conflict of interests with other users;
- A lack of opportunity, an inappropriate opportunity or a conflicting opportunity; and
- A lack of plan, an inappropriate plan or a plan conflicting with plans

The cause of planning conflicts through erroneous actions can range from misperceptions of the situation to slips such as misspelled words affecting the ability of the message to be understood. Factors at this level can have a strong influence on erroneous actions at level 3. For example a sudden distraction such as a phone call or an unexpected visitor can alter the aspects of opportunity and interest for a split second causing a distraction to the user and thus causing an erroneous action. Other examples include rushed time scales and parallel processing where the plans are inadequate for the skill of the user and thus causing rushed actions resulting in unintended actions.

### 3.2.3 Human Error at the Level of Social Context

The concepts occurring at the level of social context consist of structure, action and history. Structure relates to the social norms and pre-existing cultural orders. Actions relate to goals that arise from the present structure. Finally, history relates to changes to the structure through actions.

Structure or cultural models consider the social context in which the system will be used and have a large effect on how an agent will behave. In CSCW the social context can be different for every user involved in the collaboration. Cultural trends can range from national issues such as religious beliefs, ethics, legislation and standards to inter-personal issues such as individual beliefs and values. This is illustrated in the extension to the example scenario seen in Figure 3.3.

> Actor Y is currently going home, the reason being that he has finished work. Another actor in the group, Actor Z works for a different company also in New York but is not going home as he is working on the proposal with Actor X and wants to get the meeting finished that evening.

Figure 3.3: Collaborative human error scenario (Part 3)

Even though both Actor Y and Actor Z are on the same time scale there is a conflict in the social context due to differences in company policy. The premises in which Actor Y works close at 5:30pm. However, it is the company policy for Actor Z to allow employees to work overtime. From this example we can see that it is erroneous for Actor Y to work past 6.00 p.m. whereas it is perfectly acceptable for Actor Z to do so. In order to avoid such conflicts from occurring it is important to first establish a goal to arrange a CSCW session when all participants are available and willing to collaborate.

Actions are the development of high-level goals due to an evaluation of the environment. Goals are context dependent and different members of the collaborating group can have different goals according to the context that they are working in. The goal for Actor X and Actor Z in the example was to get the proposal agreed by the end of the working day. The goal for actor Y was to have a romantic dinner. These goals were originated through interpretations of the situation and of the opportunities available.

The presence of social norms does not mean that people have to comply with them. For example Actor Y would not have been reprimanded if he had worked beyond 6.00 p.m. but it was not his top priority to do so. Gerson and Star wrote in 1986 ‘No representation of the world is either complete or permanent’ (Robinson 1991). This is because there is no complete and permanent representation of the real world, there is only the most appropriate representation for the current social state. If Actor Y’s company begins to realise that their policy of everyone finishing at 6.00 p.m. was costing them a lot of business then this policy is likely to change. This change would not initially be favoured by the employees but after a revaluation of the situation over time it is likely that the new policy would become acceptable if it was proving profitable or avoided the need of redundancies. Non-acceptance or misperceptions of these changes can cause erroneous situations.

Many of these situations are out of our control and recovery or prevention is out of the scope of accepted collaborative studies but it is still important to take them into consideration when designing collaborative systems or planning collaborative activities.

## 3.3 Real World Examples

This section examines collaborative human error in relation to two real life examples. As in the previous section this examination is based around Mantovani's framework. The case studies come from the synopsis of two accident reports. The first case study describes an incident over Daventry, UK, involving a Boeing 737-400 en-route from east Midlands Airport to Lanzarote Airport in the Canary Islands. The second case study describes an incident near Lambourne, UK, where there was 'a loss of separation' between a Boeing 747-300 (B 747) and a Gulfstream IV (G IV) (a loss of separation relates to two aircraft being too close together whilst in flight). These two case studies have been chosen because, although both involve aviation, they offer two very different examples of collaborative human error. The intention of these case studies is not to complete a detailed analysis but to identify how real life collaborative human errors fit into a CSCW framework structure. The analysis conducted here does not attempt to propose the 'correct' reasons for these incidents occurring as only the synopsis is being used as a data resource.

### 3.3.1 The Daventry Incident

The Daventry incident is a case where human error can be seen to be experienced in asynchronous collaboration. In this case study the error is at level 1, a single user error that has repercussions in a collaborative environment. The synopsis of this case study can be seen in Figure 3.4.

> The incident occurred when the aircraft was climbing to cruise altitude after a departure from East Midlands Airport en-route for Lanzarote Airport in the Canary Islands. Following an indicated loss of oil quantity and subsequently oil pressure on both engines, the crew diverted to Luton Airport; both engines were shut down during the landing roll. The aircraft had been subject to Borescope Inspections on both engines during the night prior to the incident flight. The High Pressure (HP) rotor drive covers, one on each engine, had not been refitted, resulting in the loss of almost all of the oil from both engines during flight. There were no injuries to any crew or passengers. The aircraft was undamaged; both engines were removed and examined as a precautionary measure.
>
> *(Air Accident Investigation Branch 1996)*

Figure 3.4: Synopsis of the Daventry incident (1996)

The Daventry incident is examined from a top-down perspective in relation to the levels of Mantovani's framework. With the level of detail provided in the above synopsis it is not possible to get all the facts and many assumptions will be made. This study focuses on the failure of the engineers to do a complete maintenance check on both engines and then describes the error diagnosis and recovery procedure. Two main assumptions are made as to why this error occurred and the implications of each assumption are described.

Starting at level 1 the social context of the situation is that the owner of the airline has a responsibility, by law, to ensure that all aircraft under their control are properly maintained. The legislation which enforces this can be called a structure. Based on this structure the owner of the airline makes sure that maintenance is carried out correctly. This can be called an action. In order to ensure that this maintenance takes place and is done competently it is likely that the owner has a list of guidelines providing a structure for the maintenance of an aircraft. This list of guidelines may consist of items such as ensuring engineers are fully trained and what items should be examined in a maintenance check.

At Level 2 the situation context is that an engineer is performing the task of an engine maintenance check. The opportunity is correct in that he is present and the engine is present, he has an interest in maintaining the engine and a plan for doing it. The engineer has also received the relevant training to perform such a task.

At level 1 the local interactions involve the engineer performing actions with the objects presented to him. These actions, apart from the act of refitting the HP rotor drive covers, are not known about from the synopsis and cannot be inferred or assumed.

The human error that occurred was that the HP rotor drive covers were not refitted after the Borescope Inspection. By examining the context, described above, at each level it is possible to make assumptions as to why this occurred. The following describes two assumed reasons for the error:

The first assumption is that the engine's model in the aircraft examined was an accepted engine but not a standard one. Without knowledge of aircraft engines it is possible to assume that a standard engine does not have detachable HP rotor drive covers like the one present in the case. This means, at Level 2, the opportunity has become inappropriate for the plan in that the maintenance plan is no longer completely applicable to the engine type. At Level 3, according to Reason, the error can be classified as an 'inaccurate recall' in that the engineer forgot to replace the covers. There are also considerations at Level 1 in that an insufficient training structure has been in place that does not inform the engineer how to deal with this type of engine.

The second assumption relates to the engineer's state of mind at the time. An assumption can be made that the engineer has been working long hours during the days preceding the day of the incident. These long hours caused the engineer to be very tired when working on the engines. The assumption that the engineer was tired can provide a reason as to why the inaccurate recall, at level 3, occurred. At level 2 the interest in maintaining the engine is affected because the engineer is tired and the plan is not carried out properly. At level 1 the structure provided by the staff work schedule prevents effective maintenance as it causes its staff to be overworked.

When the pilots got into the plane they made the logical assumption that everything was in working order. Subsequent to the take off it became apparent that there were problems from examining the engine instrument system. After this detection a recovery plan was formulated and the aircraft was diverted to Luton Airport and landed safely. In this detection and recovery sequence there were structures in place for the diagnosis of problem situations and for appropriate actions based on the situation presented. These structures are formed at level 1 of the framework and led to plans being formed according to the opportunity at level 2 and finally interactions necessary to achieve the plan occur at level 3.

### 3.3.2 The Lambourne Incident

The Lambourne incident is an example of human error in synchronous collaboration. The main human error occurring in this example involves a reduction of separation between two aircraft. The synopsis of this case study can be seen in Figure 3.5.

As in the Daventry case study described earlier this examination also takes a top-down perspective of Mantovani's framework. Again, as the only information used comes from the synopsis above a number of assumptions had to be made. This examination focuses on the failure of the controller to make a correct reading of the radar display and what consequences this had on the two aircraft. Two main assumptions are made as to why this error occurred and the implications of each assumption are described.

A loss of separation occurred between a Boeing 747-300 (B 747) and a Gulfstream IV (G IV) in the London Terminal Control Area, which is Class A controlled airspace. The B 747 was en route from Kansai, Japan, to London (Heathrow) Airport; the G IV was en route from Olbia, in Sardinia, to London (Luton) Airport.

The B 747 began its descent after entering the UK Upper Information Region (UIR) from Holland and was controlled through the Clacton Sector for arrival at London Heathrow. It was cleared initially to Flight Level (FL) 290 then FL 150, and later to FL 110, whilst routing direct to the Lambourne VOR and maintaining 290 kt. On making contact with Heathrow Intermediate North Director the B 747 was cleared to descend to FL 90, to leave Lambourne on a heading of 270°, and to reduce speed 'now' to 210 kt.

The G IV entered the UK FIR from France and was controlled through the Lydd Sector for arrival at Luton via the Detling VOR. When the G IV contacted the Lambourne controlled it was level at FL 130 and was permitted to maintain high speed whilst given a radar heading of 340°, it was subsequently cleared to FL 120.

As the G IV reached FL 120 the pilot reported that his Traffic Alerting and Collision Avoidance System (TCAS) was indicating traffic in his one o'clock position. The controller initially thought that there was 1,000 feet vertical separation between the two aircraft and declared this, but he then gave the G IV avoiding action, after the pilot reported that the traffic was 300 feet below him, to turn to the left which took it out of the path of the B 747.

At the same time the B 747 crew complied with the first two TCAS Resolution Advisory (RA) messages. The first instruction was to climb followed by a subsequent instruction to descend. Subsequent analysis of the recorded radar data showed the closest proximity of the two aircraft was 0.83 nautical miles (nm) horizontally with vertical separation of 100 feet; the next element of the recorded radar data indicates that the vertical separation had been increased to 200 feet with the horizontal separation reducing to 0.66 nm.

*(Air Accident Investigation Branch 1997)*

Figure 3.5: Synopsis of the Lambourne incident (1997)

The social context of this case study is as follows. Each aircraft has a flight plan involving a destination location and an arrival location. These flight plans are a standard structure and can be assumed to have been established for many years. It can also be assumed that each aircraft is owned and operated by different airline companies and thus have different policies in regards to utilised technology and flight procedure. However, both of their flight paths are controlled by an Air Traffic Controller assigned to an airspace. The controller has a structure of policies and guidelines enforced upon him by his employer. These guidelines will inform him of procedures to follow in the case of specific situations occurring.

At the level of situation context each aircraft has different opportunities presented to them in their environment. These opportunities can include their current physical location in the sky and the technology that is available to them. They both also have varying interests though some fundamental interests will be the same such as arriving at the destination safely. It is also assumed that there are two controllers providing RA messages to each plane based on their TCAS. Each controller has the opportunity provided by the technology available and they have a common interest in maintaining a safe separation distance between the two planes.

At level 1 the local interactions are not covered in detail in the synopsis except that the crews altered direction according to RA messages received. From the synopsis provided with this incident the human error can be identified as a reduction of separation between the two aircraft beyond accepted safety standards. By examining the context, described above, at each level it is possible to make assumptions as to why this lack of separation occurred. The following describes two assumed reasons for the error.

The first assumption relates to a possibility that the structure at level 1, provided to the controllers in the form of procedure was not followed properly. The reason for this at level 1 could be that the procedure did not provide actions appropriate for such a situation resulting in improvisation. This could result in a lack of communication between the controllers and reduce their opportunities for producing an accurate diagnosis of the situation and thus reduce their ability to formulate a successful plan of resolution at level 2. This problem would be worsened at level 3, by the fact that the controller for the G IV aircraft made an initial error reading the radar display. As a result of this lack of communication the controllers formulated uncoordinated plans at level 2 which led to a further reduction in separation.

The second assumption is that the error of the controller to read the correct data from the radar display at level 3 was a direct cause of the reduced separation. The reason for this error cannot be inferred from the synopsis and could come under a number of Reason's classifications. After the controller had made this error he reported the false information to the crew of the G IV aircraft. This information was in conflict to the information available to the G IV crew who subsequently referred their information back to the controller. This new information caused the controller to reassess his opportunity and formulate a plan to increase the aircraft separation. These events reduced the amount of time to find the relevant formal procedure for such a situation resulting in the controller formulating an improvised plan based on the opportunities presented to him. As a result of this improvisation the procedure to communicate this plan to the controller directing B 747 was not followed.

## 3.4 A Model of Human Error in Collaborative Systems

This section presents a model of how human error occurs in collaborative systems based on the findings from the analysis in the previous sections.

At each level of Mantovani's framework there are interactions between three concepts that facilitate effective collaboration. At all levels two of these concepts work together in order to produce the third. At level 1 the product of structure and action is history, at level 2 opportunities and interests interact to produce goals and at level 3 tools and users interact to produce tasks. It can be seen from the analysis conducted in the previous sections of this chapter that if one or more of these concepts are missing, inappropriate or incorrect then a failure will occur. This can be illustrated by examining the following definition of human error by Bogner (1995):

> *…an act, assertion, or decision that deviates from a norm and results in an actual or potential adverse incident. The norm which defines an error is consensually accepted by the constituents of the domain under consideration.*
>
> *Bogner 1995(pg. A-24)*

If this definition is looked at in relation to the analysis conducted previously in this chapter then it can be seen that a 'norm' is not necessarily correct in itself and a norm is not always 'consensually accepted by the constituents of the domain under consideration' as a norm for one agent can be different for another. The resultant factor in the first part of this definition can be used in collaborative human error by associating the 'actual or potential adverse incident' with a failure to achieve a product at each of the contextual levels.

The products at each level of the framework consist of history at Level 1, goals at Level 2 and tasks at Level 3. In relation to human error it is not useful to view history, at

Level 1, as a product of collaboration. A more useful product for human error analysis is the action concept which is interpreted to relate to high-level goals. As 'action' is a rather indistinct term this concept has been renamed as a 'goal' and becomes the product at this level. This then affects Level 2 where the 'goal' concept is thus changed to a 'plan'. These changes do not fundamentally alter the concepts of the framework but make it more applicable to studying human error and add clarification to the terminology.

The products of collaboration at each level are now termed and defined as being:

- **Goals**: High-level goals resulting from an evaluation of the structures and being affected by history;
- **Plans:** A list of actions that can be achieved from an evaluation of the opportunities and interests present; and
- **Tasks:** Actions that are performed by a user using a tool

From these definitions interactions can still be seen to take place among the concepts at each level. A logical relationship can also be seen between these products. In order for a goal, set at level one, to be achieved a plan is formulated at level two and, in turn, tasks are performed in order to achieve the plan. From this relationship it is possible to consider the components of human error occurrence consisting of cause, event, consequence, detection and recovery. This is illustrated in Figure 3.6 and is described further in Chapter 4.

A failure to achieve a goal can be due to an inappropriate structure or through a change in the structure. An inappropriate structure to achieve a goal was seen in the Daventry incident example where it was assumed that there was an inadequate training structure to effectively achieve the maintenance goal. The change in engine type in the Daventry incident is an example of history preventing the goal from being achieved.

A failure to achieve a plan can be due to inappropriate opportunities or interests. An example of where an inappropriate opportunity caused an incorrect plan can be seen in the second assumption in the Lambourne incident where the opportunity caused the controller to formulate a plan that caused a reduced separation between the two aircraft. An example of an inappropriate interest resulting in an incorrect plan can be seen in the example scenario where Actor Y was interested in dinner rather than discussing the proposal.

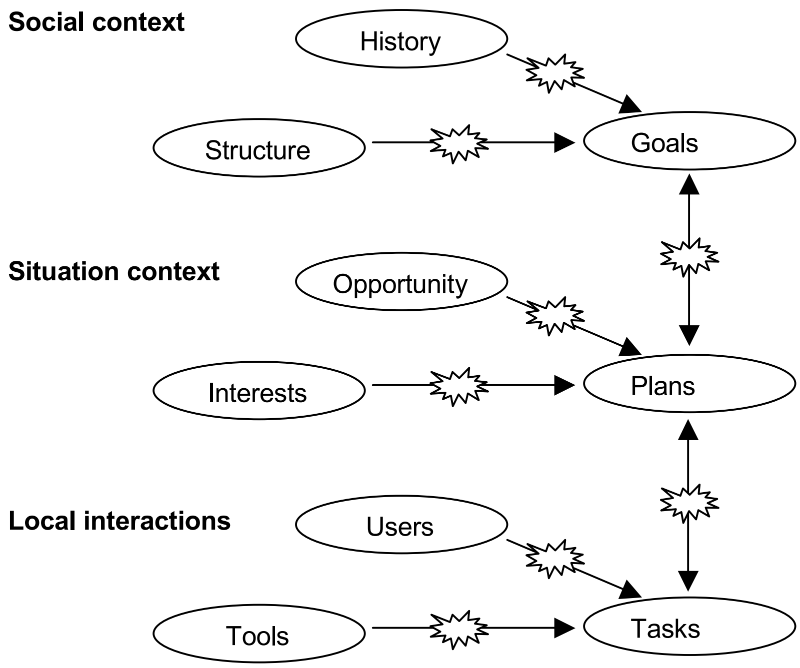


Figure 3.6: The fundamental aspects of the model of collaborative human error

Failures in achieving a task are similar to those seen in more traditional human error theories. The difference in terms of collaborative human error is that a user has to create both mental models of the system and other users. These mental models of users are created through feedback and feedthrough that are observed through changes in a tool. This similarity to single user systems suggests that a well established human error method such as Reason (1987) is best suited for examining errors at this level.

## 3.5 Summary

This chapter set out to address the first research sub-goal of examining the occurrence of human error in collaborative systems and identifying the issues involved in such an approach. This is achieved by examining examples of collaborative human error and applying them to a framework for collaboration. From this examination a proposed model of collaborative human error based on three contextual levels was described.

The following chapters present the realisation of this model of collaborative human error in a technique for examining their occurrence. Chapter 4 describes a framework to model the occurrence of collaborative human errors and a classification for their description and an approach for applying the classification. Chapter 5 describes the approach adopted for developing the model, classification and application framework. These components demonstrate the feasibility of applying this model of collaborative human error.

# Chapter 4

## 4 A Classification Model for Collaborative Human Error

In Chapter 3 the basis of a model of collaborative human error was described. This was based on an examination of examples of human error in relation to the three levels of context in the Mantovani framework. This helps to provide an understanding of collaborative human error occurrence.

The previous chapter illustrated how collaborative systems introduce many complex issues into the study of human error. In order to understand these complex issues a model was described that structured the occurrence of collaborative human error into three contextual levels. Collaborative human error was seen to result from the failure to achieve an appropriate product due to a failure, or conflict, in one of the three concepts occurring at each of these levels.

This chapter reviews the issues emerging from Chapter 3 and describes a model and classification for collaborative human error (Trepess and Stockman 1998 and 1999) that is developed through this research. The purpose of the model and the classification proposed in this chapter is to act as an aid in understanding and describing human error in complex collaborative systems. The classification is based upon elements occurring within the model. This chapter also describes a framework with which the model and classification can be applied. This is derived from applications of the model and classification to case studies and examples of collaborative human error as described in Chapter 6 and Chapter 7.

This chapter consists of three main sections. Section 4.1 describes a model of collaborative human error based on findings from the examination occurring in the previous chapter. Section 4.2 describes a contextual, three level classification for describing human error according to the collaborative human error model. Finally, Section 4.3 describes an application framework by which the classification model can be applied to erroneous situations.

## 4.1 The Model of Collaborative Human Error

The basis of the model of collaborative human error was derived from the research described in Chapter 3. This research suggested that a collaborative human error could occur at and evolves through three contextual levels and was caused through conflicting concepts occurring at each level. The initial model was applied and developed through a series of case studies to result in the model described in this chapter. These applications are described in later chapters of this thesis.

This section starts by describing some terms and definitions that were derived for this study and is followed by a description of the scope encompassed by the model. The remaining parts describe the model of collaborative human error, the components of their occurrence and the level at which they can occur.

### 4.1.1 Definitions of Collaborative Human Error

During the development and application of the model it became apparent that current human error definitions are no longer totally applicable in the context of collaborative environments. The definitions derived for collaborative human errors are as follows:

1) **Collaborative human error** – A series of collaboration failures leading to and resulting from an erroneous situation; and
2) **Erroneous situation** – The occurrence of a situation resulting from collaboration or having an impact upon subsequent collaboration that is regarded to be undesirable by one or more collaborating agents.

These terms were defined as a result of a realisation that collaborative human errors are not single events but occur over a period of time and result from or impact upon collaboration. The following section describes the scope covered by the model of collaborative human error.

### 4.1.2 Scope of a Model of Collaborative Human Error

The terms defined in the previous section describe how collaborative human errors involve the collaborations that impact upon or are impacted by an erroneous situation. This means that when studying collaborative human errors it is important to understand the context of the events that precede and follow the erroneous situation. The extent to which these need to be understood is described in this section.

The original model of collaboration that forms the basis of the model of collaborative human error describes three contextual levels that encompass an understanding of collaboration. These levels include social context, situation context and local interactions and reflect the scope of the model of collaborative human error. The following describes each contextual level in terms of how they define the scope of the model of collaborative human error.

#### 4.1.2.1 Local Interactions

The level of local interactions describes the interactions of individual agents that occur immediately before, during and after the occurrence of the erroneous situation. This level involves the agent, the tools they use, the tasks they perform and uncontrollable events that occur that are within the direct context of the erroneous situation. A study at this level can be conducted at varying levels of detail in terms of the identification of tools and tasks.

A tool is defined as an object that is created to serve a purpose. These objects can be physical in terms of machines or software, or cognitive in terms of knowledge. Tools can be examined at different levels of detail in terms of the different relationships they have to other tools. A tool can be of a similar type to another tool or a tool can be a part of another tool. For example, a Boeing 747 and a Harrier Jump Jet are of a similar type in the sense that they are both aeroplanes whereas the ‘spelling and grammar’ tool is a tool that exists within Microsoft Word. The level of detail at which these relationships are examined depends on the purpose of the examination and the available information.

Automated technologies should also be included when examining the tool concept. Automated technologies can perform tasks and use tools in a similar way as an agent and can contribute to the occurrence of a collaborative human error. This means that automated technologies do not fit neatly within either the 'tool' or the 'agent' concepts at this level but are referred to as tools because they share no other attributes with agents such as the ability to have goals or form plans. Erroneous situations contributed to by automated technologies are said to include a technical failure of the tool.

A task is an action, or a series of actions, that is performed by an agent using a tool to achieve the goal of a plan set at the level of social context and situation context respectively. A task can be broken down at varying levels of detail. At a high-level a series of actions can be referred to as a single task. For example, the task of saving a document requires that the 'File' menu is clicked and the 'Save' or 'Save As' function is selected. In some cases it might be necessary to refer to each keystroke as a single task.

#### 4.1.2.2 Situation Context

The level of situation context is the central level of the model and is impacted upon by decisions made at the level of social context and by interaction made at the level of local interactions. This level involves the opportunities, interests and plans involving groups of collaborating agents within the context of the erroneous situation.

Situation context can be studied in relation to individual agents or groups of agents. This is possible when groups of interacting agents are all working in similar situations. For example, the Commander and the First Officer working on the flight deck in a Boeing 737 can be assumed to have very similar opportunities, interests and plans and thus they can be treated as a single agent group. At a more detailed level the agents in this group may need to be treated individually should significant differences be detected.

Opportunities are the elements that are present to enable a plan to be achieved. Opportunities may derive from rules and procedures set at the level of social context or from the tools that exist at the level of local interactions. Opportunities may consist of cognitive concepts such as the presence of knowledge or an acquired skill or opportunities may consist of physical objects such as tools. The absence of an opportunity or its existence in a limited form will reduce the ability of a plan that utilises that opportunity to be achieved.

An interest is the foremost attention focus of an agent at a single point in time. An interest can be triggered by the opportunities that are presented to an agent through the existence of tools, or information or through the interests of other members of the collaborating team. An interest is then converted into a plan based on an evaluation of the interest and the available opportunities. Interests can be hard to observe and can be difficult to distinguish from a plan because they often only become observable through a plan being conducted. In most cases an interest can only be inferred based on the opportunities that exist and the plans that are conducted. A collaborative human error involving the interest concept is often easier to detect when an appropriate interest appears to be absent.

A plan is the formation of a task sequence, based on an evaluation of opportunities and interests, that can be carried out to address the goal set at the level of social context. A plan consists of a sequence of tasks that are conducted at the level of local interactions. A collaborative human error that is contributed to by an erroneous plan will be where an inappropriate plan is formulated. A plan might be inappropriate in terms of the opportunities that are present, the interests that an agent has or alternative plans that are formulated by other agents.

#### 4.1.2.3 Social Context

The previous sections have described the scope of collaborative human errors at the levels of local interactions and the level of situation context. At the level of local interactions the scope was very narrow and dealt with individuals and the contextual elements that are very specific to the tasks that that individual performs. At the level of situation context the scope widens to include agents as part of a collaborating group. The scope continues to widen when studying the level of social context. This level involves the structures, history and goals involving groups of collaborating agents and organisations within the context of the erroneous situation.

Social context can be studied in relation to individuals, groups or organisations. An individual, a group or an organisation can set each of the concepts at this level. Even though an organisation is not directly involved in the erroneous situation they can play a major role in creating the context in which it occurs and that contributes to its occurrence.

Structures are rules and procedures by which people operate. At a national level these may consist of laws and legislation set by government. At an organisation level these may include work practices, training, safety procedures and project management. At an individual level these structures may be beliefs, principles and informal work practices.

History relates to previous events that impact upon structures and goals that are set at this level. At individual, group and organisation levels this can refer to lessons that should have been learnt from previous experience such as previous decisions or events that proved to be erroneous. It can also relate to a lack of past experience that impacts upon the ability to select appropriate structures or derive appropriate goals.

Goals are the high-level aims of a collaborative activity that are derived from structures and from previous experience. The goals that are created trigger the collaborative processes that occur at the lower levels. They determine the plans that are set at the level of situation context and the tasks that are performed at the level of local interactions.

This section has described the scope that is encompassed within the different levels of the model of collaborative human error. The section has illustrated how the scope of examination is narrow at the level of local interaction and becomes wider as examination explores the higher levels. The following section describes a model that illustrates how collaborative human errors evolve through the three levels.

### 4.1.3 A Model of Collaborative Human Error

The model seen in Figure 4.1 is an extension of the revised Mantovani framework of collaboration and is derived from the examination of human error described in Chapter 3. These revisions include alterations in regards to the position of the goal and plan concepts. Mantovani's framework is extended by identifying the products that are achieved at each level and then identifying the elements that conflict to prevent them from being produced correctly, if at all. The revised Mantovani framework is displayed on the left hand side of the model in Figure 4.1 and the products that are achieved are displayed in the right hand side of the model. The basis of the model is that a human error can occur at each level through conflicts between two concepts interfering with a product.

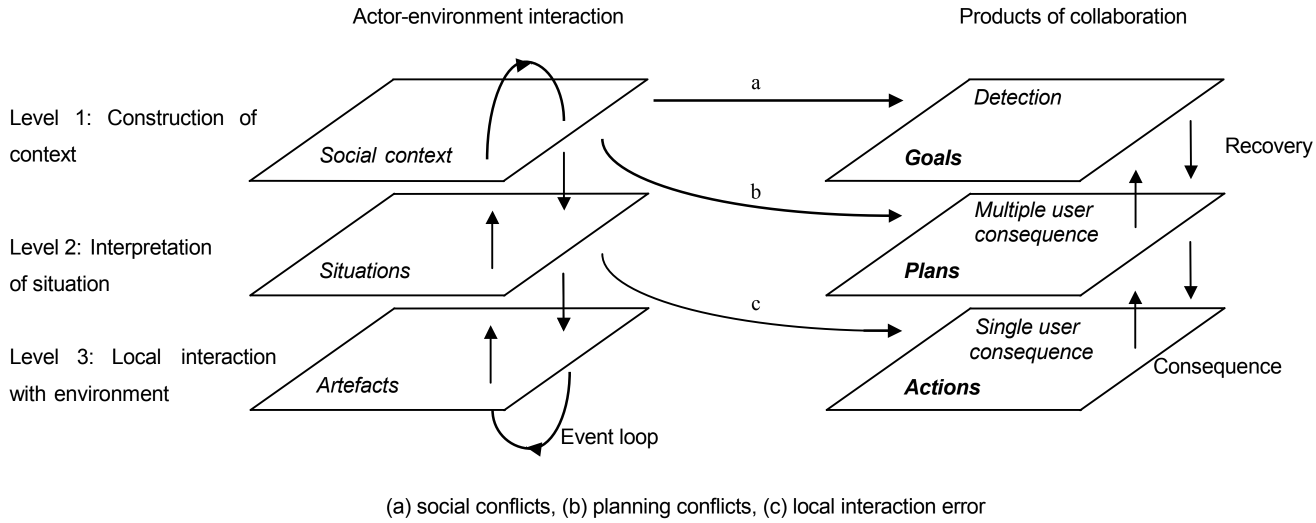


Figure 4.1: Proposed model of collaborative human error

The model in Figure 4.1 shows where the components of collaborative human error occur in relation to the three levels of context and the products that are achieved at each level. The components described in this section consist of cause, consequence, detection, recovery and the event.

Cause refers to the reasons why a human error has occurred. In relation to the three contextual levels an error can be caused at either level 1 or level 2. It can be argued that an error cannot be caused at level 3 if it is believed that an error cannot occur as a result of a faulty plan or goal. This belief can even be applied to slips, for example when a person is typing a word using a keyboard and hits an incorrect key. This type of error would, traditionally be called a slip and its cause would be placed at level 3. However, it can also be interpreted to be caused by an inappropriate plan to type the word too quickly for the user's ability and therefore be caused at level 2. The implications of this second interpretation are that it suggests that human error can be absolutely prevented in systems design which is not the case and nor is it, in many cases, desirable. In this research it is suggested that human error cannot be caused at Level 3. The reason for this is that in a study of causality in collaborative human error the focus is on how a failure in collaboration can affect human error and this implies a plan always being in existence. However, it is recognised, in this research that human error cannot be absolutely omitted through design.

The consequence of an error is initiated by interactions at level 3 and has an impact on collaboration at Level's 1 and 2. Human errors at this level are active failures and can only have SUC in a similar form to those seen in single user systems. Once the consequences appear in Level 2 and Level 3 they are latent failures and can be said to be MUC. An error can be made at Level 1 but not become erroneous until placed into a multi-user context. This was seen in the Daventry case, described in the previous chapter, where the engineer forgot to replace the HP rotor drive covers on both engines. The pilots did not perceive the consequences of this action until placed into the context of flying the aircraft. An event, also, may not be erroneous in a single user context and may only become erroneous when placed into a multi-user context. An example of this can be seen in a situation where a message is sent and its contents conflict with a receiver's interest or opportunity in some way. A consequence that only has SUC can deviate from a goal but this goal is modelled in the user concept at Level 3.

Error detection is made at Level 1. This is because an error can only be detected when its consequences are perceived to deviate from the goal set at this level as was stated by Hollnagel (1993) who says that:

> *"In practice…erroneous actions are not usually observed when they occur but are detected when they have consequences."*
>
> *Hollnagel 1993 (p.30)*

An example of this was seen in the Daventry incident where the detection occurred after the consequences indicated that the goal of arriving at the destination could not be achieved.

The process of error recovery also begins at this level. The error recovery plan has to start with the formulation of a goal followed by the formulation of the plan followed by the actions necessary to carry it out. In the Daventry incident once an error had been detected a new goal was collaboratively set to divert to Luton Airport.

The event loop illustrates that erroneous actions can occur and have consequences at any level of the model. For example a social conflict at the level of social context will cause revisions to the plan at the level of interpretation of the situation that in turn will effect the local interactions with the interface. Likewise an error at level 3 that has MUC's will cause errors in the plan at level 2 and result in deviations from the goal at level 1. Examples of this can be seen in both of the main causal assumptions found in the Daventry and Lambourne incident examination.

### 4.1.4 Levels of Collaborative Human Error

The model in Figure 4.1 describes how the failure to achieve an appropriate product at each level can be classified. A human error caused at level 1 can be classified as a social conflict(a). At level 2 an error can either be classified as a planning conflict(b) where the plan is not achieved or a local interaction error(c) at level 3 where the task is not achieved. This is because it has been assumed that all errors must have an associated plan or structure in order for them to occur.

Social conflicts are conflicts of socially imposed goals of different groups or individuals participating in the collaboration. Errors at this level deal in the relationships between the structure, action and history present for an actor and between other actors in the collaborating group. The structure is defined as the social norms present in a situation, history is defined as a change to these social norms and a goal is defined as the objective of a social group. In Chapter 3 it was stated that there were two sub-levels to examining human error at this level of context. These were examining the structures that indirectly and directly affected the production of a goal. The structures that can directly affect the production of a goal can be found through examining the elements of social awareness (Gutwin and Greenberg 1995) and the interactive social protocols (Salvador et al. 1996).

Planning conflicts occur when there is a conflict in plans arising from differences in opportunities and interests. An opportunity is what a situation state allows an agent to perform and thus is a description of the situation state. An interest can be defined as something an agent or organisation wishes to achieve. A plan can be defined as a list of actions that will achieve a goal. Planning conflicts can be identified through examining the elements of workspace awareness (Gutwin et al. 2001) and the issues of interactive situations (Salvador et al. 1996).

Local interaction errors are low-level interaction errors caused by inappropriate planning at level 2. Failures at this level can involve conflicts between user, tool and task in respect to a user's local environment. A failure at this level can also include a technical failure of a tool.

These three error types form the three main error classifications providing the basis for the main classification. The classification for collaborative human errors is described in Section 4.2.

## 4.2 A Classification for Collaborative Human Error

The classification is based around conflicts in achieving a product at each of the three levels of the model. These products are goals, plans and tasks. These products are obtained through the interactions between the elements occurring at each level. At this stage in the classification description an erroneous situation will be described as a conflict between these elements or between two occurrences of the same element. At a high-level of abstraction the classification can be seen to consist of three major types:

(a) Social conflicts;
(b) Planning conflicts; and
(c) Local interaction errors

In the following sections these three main classification types will be expanded to define error types occurring within each. These more specific error types will then form the operational part of the classification. The classification is based on conflicts among the concepts present at each level of the model. At this stage of the description all combinations of conflict, including conflicting products, will be described as a classification type.

### 4.2.1 Classification of Social Conflicts

The classification, at this level, consists of the elements of structure, goal and history. History relates to changes in culture, work procedure and individual behaviour. Structure relates to established norms of a culture, an industry or an individual. Goal relates to the goals of a nation, an industry and a person. The goal classification at this level will substitute the term of 'intention' used in traditional error classifications.

Within this classification there are 6 main error types that can occur for each element of social conflict. These are:

**Classification of social conflicts**

1) Conflicting structures;
2) Conflicting histories;
3) Conflicting goals;
4) Conflicting history and structure;
5) Conflicting history and goal; and
6) Conflicting structure and goal.

The ***conflicting structure classification*** type can be defined as a situation where a social norm in one environment conflicts with a social norm in another. For example conflicting legislation at a national level, conflicting policies at a corporate level and conflicting work practices at a personal level. An example of this error type can be seen in the case of the example scenario where it is the social norm for Company B to close its building at 6:00 p.m. whereas it is company policy for Company C to provide 24hr access. This resulted in Actor Y being on the train at the time of the meeting. Another example from the example case study is the different time zones in which Actor X and Actor Y were working.

The ***conflicting history classification*** type can be defined as a situation where a social change in one environment is in conflict with a social change in another. This should not be confused with a conflict of structure. The difference between the two is that a change in at least two different structures in the collaborating group must take place for the classification to apply. This can include changes in legislation at the national level, changes in policy at the corporate level and changes in work practice at the personal level. An example can be seen in the case of Company B changing its opening policy to provide 24 hr access but Actor Z being absent as he has recently got married and will be spending more time away from the work place for the next few weeks.

The ***conflicting goal classification*** type can be defined as a situation where a national, corporate or personal objective conflicts with another. For example the goal behind Company B changing their opening policy could be to allow staff to work overtime whereas it is Actor Z's goal to get married. In a personal context caution must be taken in differentiating between a goal-orientated classification type at the social conflict level with an interest conflict classification at the level of planning conflicts (defined later). The classification must only be used in relation to the level of social context.

The ***conflicting structure and history classification*** type can be defined as a situation where a present structure conflicts with a changing one. An example of this can be seen in the scenario where Actor X, Actor Y and Actor Z are working together and have established a successful work practice over the past 2 years. Should Company A alter this work practice, adversely, by increasing Actor X's work load then a conflict of structure and history has occurred.

The ***conflicting structure and goal classification*** can be defined as a situation where a goal is inappropriate in relation to a structure. The important aspect of this classification is how it occurs in a national, corporate or personal context. There are goals set within each context and an inappropriate structure can cause a deviation from any of these goals. An example of this error type can be seen using the example scenario. The goal set in the example scenario was to review the proposal but if there is no structure for this review process, in terms of an agenda, then the review process will not run as effectively.

The ***conflicting history and goal classification*** type can be defined as a situation where a goal cannot be achieved due to a changing structure. As with the conflicting structure and goal classification national, corporate and personal context is the important feature in this classification. In the example scenario this error type can be seen if Company A were to update the collaboration software but the new software would not support the task of reviewing the proposal for some reason. A reason for this may be that the software had compatibility problems with an agent's machine preventing a connection being made.

Table 4.1: Error classification table for social conflicts

| Classification | Description |
|---|---|
| Conflicting structures (STR:STR) | A situation where a social norm in one environment conflicts with a social norm in another. |
| Conflicting histories (HIS:HIS) | A situation where a social change in an environment is in conflict with a change in another. |
| Conflicting goals (GL:GL) | A situation where a national, corporate or personal objective conflicts with another. |
| Conflicting history and structure (HIS:STR) | A situation where a present structure conflicts with a changing one. |
| Conflicting history and goal (HIS:GL) | A situation where a goal cannot be achieved due to a changing structure. |
| Conflicting structure and goal (STR:GL) | A situation where a goal cannot be achieved due to a changing structure. |

This section has described and defined the classification subset for social conflicts that are summarised in Table 4.1. The following section describes the classification subset for planning conflicts.

### 4.2.2 Classification of Planning Conflicts

As a plan comes as a direct result of an evaluation of the opportunities and interests presented it is important, when classifying an erroneous situation, that these elements are not confused with each other. It must be remembered that an interest is something a person wants to do or think about whereas a plan is purely a list of related actions. Within this classification there are 6 main error types that can occur for each element of planning conflict. These are:

**Classification of planning conflicts**

1) Conflicting opportunities;
2) Conflicting interests;
3) Conflicting plans;
4) Conflicting opportunities and interests;
5) Conflicting opportunities and plans; and
6) Conflicting interests and plans.

The ***conflicting opportunity classification*** type can be defined as a situation where there is an erroneous situation through adverse opportunities existing between multiple agents. In the example scenario introduced in Chapter 3 the fact that Actor X and Actor Y were working in different physical conditions is a good example of this classification type.

The ***conflicting interest classification*** type can be defined as a situation where there is an erroneous situation through conflicting interests between multiple agents. In the example scenario the interest of Actor X was to discuss the proposal whereas the interest of Actor Y was to think about dinner. Another example can be seen in supporters in a football match. If Stoke City are playing Wigan at football a Stoke supporter will not have the same interests as a Wigan supporter. Neither supporter has any influence in affecting the result of the match meaning the plan element does not exist.

The ***conflicting plans classification type*** can be defined as a situation where there is an erroneous situation through a plan being performed correctly but causes a conflict in relation to other plans. Following the situation seen in the example of the goal and structure conflict where there is no agenda for the meeting an error of conflicting plans can occur if Actor X and Actor Y have both formulated two different and incompatible plans to deal with the proposal.

The ***conflicting plan and opportunity classification*** type can be defined as a situation where a plan has been formulated but the opportunity is inappropriate. For example, the plan to conduct the meeting was made but the fact that Actor Y had forgotten important information means that his opportunity was not appropriate to perform the plan. A further example can be seen when Pete forms a plan to play a game of tennis with Andre on a grass tennis court on Saturday, they get to the court and it starts to rain. In this example the plan is to play a game of tennis but the opportunity has ceased to exist as it is raining.

The ***conflicting interest and plan classification*** type can be defined as a situation where a plan has been formulated but there is an inappropriate interest from a participant. For example, the plan is to review the proposal at a specific time but Actor Y's interest was in thinking about dinner. On first appearances this appears similar to conflicting interest but the difference is a plan has been formulated to have the meeting at that time and it is this that is in conflict with Actor Y's interest.

The ***conflicting opportunity and interest classification*** can be defined as a situation where there is an inappropriate interest for an opportunity. An example can be seen in the example scenario where Actor Y has the interest in reviewing the proposal but the opportunity presented him being on the train is not conducive to work. People, events and noise on the train can act to distract Actor Y's interest.

This section has described and defined the classification subset for planning conflicts that are summarised in Table 4.2.

Table 4.2: Error classification table for planning conflicts

| Classification | Description |
|---|---|
| Conflicting opportunities (OP:OP) | A situation where there is an erroneous situation through different opportunities between multiple agents. |
| Conflicting interests (INT:INT) | A situation where there is an erroneous situation through conflicting interests between multiple agents. |
| Conflicting plans (PL:PL) | A situation where there is an erroneous situation through a plan being performed correctly but causes a conflict in relation to other plans. |
| Conflicting opportunities and interests (OP:INT) | A situation where there is an inappropriate interest for an opportunity. |
| Conflicting opportunities and plans (OP:PL) | A situation where a plan has been formulated but there is an inappropriate interest from a participant. |
| Conflicting interests and plans (INT:PL) | A situation where there is an inappropriate interest for an opportunity. |

To clarify the distinctions between the plan and interest types at this level the following scenario is examined. Bob is reading a document on a piece of paper because he has an interest in its content. Karen picks up the piece of paper Bob is reading and makes a paper aeroplane out of it and throws it. In this example Bob's interest was in the contents of the document whereas Karen's interest was in the paper it was written on. As the document is no longer there Bob's interest is no longer on the document content. This is a conflict of interests because Bob's interest was on reading the document whereas Karen's interest was on making aeroplanes. If there were two pieces of paper on the desk and Karen picked the one Bob was reading then it would be a conflicting plan and interest because Karen formed a plan to pick the paper that Bob was reading. In this case it is Karen's plan to pick the paper Bob is reading as opposed to the one he is not that is destructive. Take away both pieces of paper from the environment and it is an error of opportunity and interest as there is no point in planning to make a paper aeroplane out of paper that is not there. The interest is still there but there is no plan.

The following section describes the definitions for the classification subset for local interaction conflicts.

### 4.2.3 Classification of Local Interaction Errors

At this level errors can by classified using Reason's 1990 classification of failure modes at the skill-based, rule-based and knowledge-based level. Reason’s classification was chosen due to its generalised nature that meant it would not intrude on and complicate higher levels of the model and could be extended to classify human error in collaborative systems at the local interaction level. Reason's classification is also the recognised standard in human error analysis. The classification of errors at level 3 can be seen in Table 4.3.

Table 4.3: Error classifications at the level of local interactions

| **Conflict/ local interactions** | **Tool** | **Users** | **Task** |
|---|---|---|---|
| Skill based (SB) | Error through misrepresentation of tool | Error through misrepresentation of users | Error through Misrepresentation of task |
| Rule based (RB) | Inappropriate tool selected | Inappropriate user selected to interact with | Inappropriate task selected |
| Knowledge based (KB) | Error through lack of knowledge of tools | Error through lack of knowledge of users | Error through lack of knowledge of tasks |
| Technical failure (TF) | Technical breakdown | N/A | N/A |

The classification provided by Reason has been extended to show how it relates to the components of tools, users and tasks present at level 3. This also extends the classification to enable it to be applied to local interactions with groupware systems. A further classification type of 'technical failure' has been added to the classification. This is because human errors at levels 1 and 2 can cause technical failures at level 3 that, in turn, have consequences at all levels.

## 4.3 An Application Framework for the Classification Model

In order to evaluate the classification model proposed in this thesis it is necessary to apply them to examples of human error. Through applying the classification model to the case studies described in the following chapters an application framework has emerged that provides a more structured application of the classification model for the examination of collaborative human error.

The classification model is applied through four main stages that are common to many human error analysis methods. These stages facilitate knowledge acquisition, structure and analysis. The stages of application are as follows:

1) Knowledge acquisition;
2) Building the task and context description;

3) The application of the classification and description; and
4) Classification analysis.

These four stages of the framework are iterative. When conducting the analysis conclusions can be drawn which require further knowledge acquisition, description, classification and analysis. The stages can also be conducted in parallel to each other. For example, the task and context description may be constructed at the same time as the knowledge elicitation takes place. The knowledge acquisition stage is not an integral aspect of this research as it uses the same tools as any other method that requires knowledge acquisition.

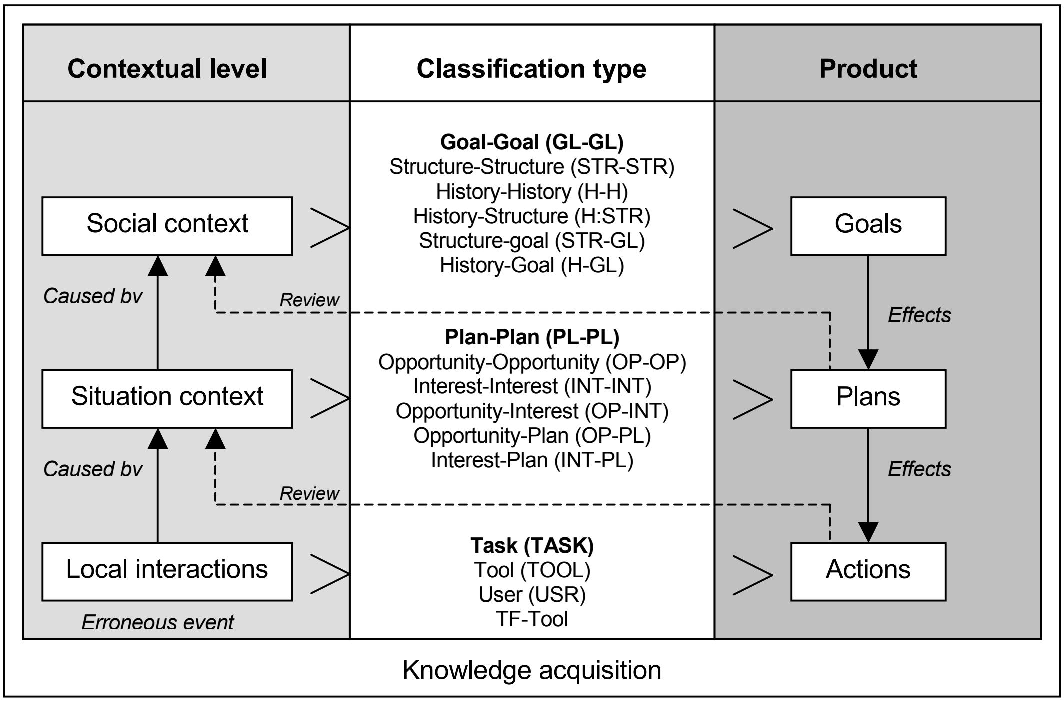


Figure 4.2: The underlying framework for applying the proposed model

The underlying framework for applying the classification model in Figure 4.2 shows how collaborative human errors can be examined both from a top-down and a bottom-up perspective. The top-down perspective examines human error by first identifying where a goal has not been achieved then examining the concepts at lower levels of the model to understand why it occurred. The bottom-up perspective starts by identifying errors at the level of local interaction and looking at higher levels to understand what caused it and what were the consequences of its occurrence.

In order to apply the classification model a process of knowledge acquisition is required to identify information related to the erroneous situation. The knowledge that is acquired about the erroneous situation is crucial to the success of the analysis. Stage 2 relates to the construction of the task and context models. The task and context descriptions place this knowledge into task and context structures building up the picture of the event on the left-hand side of the diagram (Figure 4.2). Stage 3 involves the identification, classification and description of conflicts that have an impact on human error. This shows how the contextual elements on the left-hand tier of the diagram are classified by the taxonomy according to conflict type in the middle tier and which product is not produced as intended on the right hand tier. The final stage, Stage 4, is to use this structured contextual human error description to analyse cause and effect of collaborative human error.

The following sections describe the four stages that are undertaken to apply the classification model. The first section describes stage 1, the knowledge acquisition process. The second section describes stage 2, the construction of the task models and the context description. The third section describes stage 3, the process of applying the classification to human errors and how to expand on the classification by including elements of context. The final section describes stage 4 in relation to how this error description can be used for the analysis of collaborative human error and identifies possible application areas for the results of the analysis.

### 4.3.1 Stage 1: Knowledge Acquisition

The knowledge acquisition stage should gather information that corresponds to the scope of the model of collaborative human error as defined in Section 4.1.1 of this chapter. A variety of standard knowledge acquisition techniques can be used for this stage. In this research knowledge was acquired from paper-based case-studies and through a combination of interviews, focus groups, observations and participation. The concepts within the model of collaborative human error and the results of a task analysis (as part of stage 2) helped to direct the type of information that was acquired.

### 4.3.2 Stage 2: Building the Task and Context Structure

Stage 2 structures the data that was acquired during stage 1. The knowledge is structured using a task analysis method and context tables. The task analysis is employed for structuring knowledge relating to goals, plans and tasks to understand the interactions that were conducted. Context tables are used to describe the context that exists in an erroneous environment at each contextual level. The procedure for Stage 2 is as follows:

1) Conduct a task analysis to identify goals, plans and tasks;
2) Segment the study into manageable sections;
3) Construct a social context table for the overall situation; and
4) Construct context tables for each of the three contextual levels.

The above procedure can either begin at contextual level 3 or level 1 of the collaborative human error model depending upon whether a top-down or bottom up perspective is taken. The following sections describe the knowledge structures that are constructed.

#### 4.3.2.1 Constructing the Task Analysis

The first stage of organising the data obtained from the knowledge acquisition activities is to understand the tasks that were conducted before, during and after the erroneous situation. The most common mechanism for this is to organise the task information using some form of task analysis method. A task analysis is constructed for three main reasons in relation to collaborative human errors.

1) To understand the high-level tasks and the local interactions that were conducted in relation to the erroneous situation;
2) To segment a large case study into small manageable segments according to the high-level tasks; and
3) To aid in distinguishing between goals, plans and tasks that exist in relation to the erroneous situation.

Task analysis is a common technique for human error analysis. An example can be seen in THEA (Technique for Human Error Analysis) (Pocock et al. 2001) which used hierarchical task analysis (HTA) as a method of structuring tasks. However, the ability of many task analysis methods to model group interactions is limited. Some methods that do provide group interaction support such as Groupware Task Analysis (GTA) (Van der Veer et al. 1996) and Programmable User Modelling Analysis (PUMA) (Blandford and Good 1998a a and 1998b).

Both of these methods, and other methods that model group tasks, can be used in structuring the task information. In this thesis GTA is used due to its graphical nature that makes it easy to present and understand and the way it combines task and context through the creation of the task models.

The first purpose of the task analysis is to gain an understanding of the high and low-level tasks that occurred in relation to the erroneous situation. This helps in identifying where collaborative human errors have occurred, the tasks that they relate to and the people that perform them. At the top level this aids in providing an overview of the task context in which the erroneous situation occurred. At a low-level this aids in providing a detailed view of the interactions that are conducted with the tools during an erroneous situation.

The second purpose of the task analysis is to enable a large study to be segmented into manageable segments in a logical manner. Some studies can be very large and span a long time scale. To ease the examination of the context tables described later in this chapter these large studies can be segmented according to the boundaries defined by high-level tasks in the task analysis.

The third purpose of the task analysis is to aid in distinguishing between goals, plans and tasks. During the studies conducted in this research it became apparent that it was difficult to decide whether an action was a goal, plan or a task because they are all closely related to each other and are only differentiated by the contextual level at which they relate. The task hierarchies produced in the task models aided in selecting the appropriate concept for the examination.

A benefit of using GTA is the way in which it structures contextual information of tasks in terms of providing models for agents, roles, objects and events which fits well with the model of collaborative human error.

Tasks, in the task tree, are performed by ***agents***. Agents relate to the individuals or groups of individuals involved in performing the tasks. In GTA an agent can also relate to system agents such as the automated devices.

Each agent has a ***role*** that is played in a situation. A role is a set of tasks that is assigned to an agent. The role that is assigned to an agent will have been done so, at level 1 of the collaborative human error model, through communication and discussion with other members of the group and the organisation they work for. By identifying the roles that agents play it is possible to get a view of who is responsible for certain tasks.

A task is performed using ***objects***. As it has been mentioned before there are both physical and conceptual objects that are used in a task. GTA mainly models physical objects. The conceptual objects are implied through communication tasks.

The final concept described by GTA is ***events***. Events describe circumstances that occur outside of the agent's control in the context of the erroneous environment. An event may reflect a change in an internal concept such as object, task, agent or role or an external concept such as a change in the weather or a change in the quality of a network connection. A change in one or more of these internal or external concepts may trigger a task to be performed that may not normally be performed.

Many of the purposes of performing a task analysis described above can be achieved using a traditional task analysis approach such as HTA. GTA produces task trees in a similar way to HTA but provides added value in modelling the contextual elements relating to the collaborative nature of each task that can be expressed within a tabular form. An example of the tabular form can be seen in Table 4.4 that relates to the "connect to internet" task from the illustrative example.

Table 4.4: Tabular GTA context description for the connecting to the internet task.

| | | | |
|---|---|---|---|
| **Name** | Connect to internet | **Initial state** | not connected to internet |
| **Goal** | Establish a network connection | **Final state** | connected to internet |
| **Task type** | | **Start condition** | |
| **Constructor** | | **Stop condition** | |
| **Sub tasks** | | **Used objects** | Dial-up link<br>Groupware tool<br>Laptop |
| **Performed by** | Actor X<br>Actor Y<br>Actor Z | **Duration** | |
| **Involved roles** | Assess proposal<br>Husband<br>Present proposal | **Frequency** | |
| **Triggers** | | **Media objects** | |
| **Triggered by** | Network failure | **User actions** | |
| **Comments** | | **System operations** | |

These elements can then be transferred into the context tables for the collaborative human error being examined as described in the following section.

#### 4.3.2.2 Creating the Context Tables

The model of collaborative human error requires that a large amount of data is acquired that describes the context of an erroneous situation. This information needs to be organised within some form of logical structure. In this research the data was organised into "context tables". Context tables organise the data according to the elements existing at each contextual level of the model. This section describes the context tables at each level of the model and describes how they benefit a study of collaborative human error.

### *Social Context Tables*

There are two forms of context table that can be produced at the level of social context. These include the following:

1) Overview context table; and
2) Task specific context table

The overview context table describes the social context that describes the high-level context that applies to the entire erroneous situation. This type of context table is only necessary for large-scale erroneous situations that encompass a wide contextual scope and that involve large amounts of contextual data. This type of contextual data lists the main elements of social context that apply to each high-level task identified through the task analysis. An example of this overview context table can be seen in Table 4.5.

Table 4.5: Overview context table of social context

| Project area | Goals | Structures | History |
|---|---|---|---|
| Task 1: Review proposal | Get proposal accepted | Review procedure, review team, time-scales, organisation procedures, international time-zone | Experience of reviewing proposals, experience of submitting proposals |
| Task 2: Travel home | Get home in time for dinner | Train timetable | |
| Task 3: Arrange dinner | Book a nice restaurant | Table bookings | Forgotten anniversary |

The overview context table is split into four columns. The first column describes the high-level tasks that were identified in the example case study described in Chapter 3. The following columns describe the contextual elements in terms of the overall goal to be obtained from each task, the structures that are impact upon the task and the historical elements that could affect the task outcome.

The second form the social context table examines each of the high-level tasks in detail and organises the data according to each agent and each contextual element. An example context table for the example case study can be seen in Table 4.6.

Table 4.6: Social context table for the example case study

| Agent | Goals | Structures | History |
|---|---|---|---|
| Company A | Get proposal accepted | [organisation procedures: Policy of 24 hour Access, review procedure], international time zone, time-scale | Expertise, reputation |
| Company B | Discuss proposal, increase productivity | [organisation procedures: Close building at 6:00pm, review procedure], time zone | Experience of low productivity |
| Y Family | Celebrate anniversary | Anniversary | Forgot last years anniversary |
| Actor X | Get proposal accepted | Proposal, working relationship with Actor Z | Experience of submitting proposals |
| Actor Y | Discuss proposal | Anniversary, train timetable, proposal | Experience of reviewing proposals |
| Actor Z | Get proposal accepted | Working relationship with Actor X | Experience of submitting proposals |

The context table in Table 4.6 describes the social context that applies to each agent involved in the example case study. The agents include individuals, groups and organisations. In larger studies separate tables may be created for organisations, the groups that exist within them and the individuals forming the group. This forms a hierarchy of social context tables. In this research the term agent is used to refer to organisations, groups and individuals.

When describing the social context there are three main types of information that can be captured:

1) International information;
2) Organisational information; and
3) Personnel information.

***International*** information relates to legislation, time differences and languages that may have an impact on an erroneous environment. An example can be seen in a collaborative community involving participants in the USA and participant in the UK. The time difference is so large that arranging synchronous meetings is difficult. ***Organisational*** information relates to the organisations that agents belong to and organisations that affect the way that they work. ***Personnel*** information relates to the roles and responsibilities that are assigned to groups and to the individual agents within those groups. A group is formed to perform a certain task and the members within those groups each have different roles and responsibilities in carrying out the task.

The social context for each agent is described in terms of goals, structures and history. At this level agents are assigned contextual elements that they have responsibility for. This means that an agent has either created the element or has influenced the decision for its selection but does not necessarily mean that they use it. This is particularly relevant to structures that are set by organisations. An organisation sets a structure that its employees have to comply to. This structure is assigned to the organisation and not the employee. This allows a collaborative human error at this level to be traced back to those that are responsible for its existence.

### *Situation Context Tables*

The situation context tables organise the elements applying to the situation context for each of the high-level tasks identified through the task analysis. These contextual elements relate to opportunities, interests and plans and are organised according to the agent they apply to. An example situation context table for the example case study can be seen in Table 4.7.

Table 4.7: Situation context table for the example case study

| Agents | Opportunities | Interests | Plans |
|---|---|---|---|
| Actor X | [time-zone: New York time], proposal, people are available, experience [technology: computer, groupware software, unreliable communication channel] | Get proposal accepted | Discuss the proposal using the distributed communication channel |
| Actor Y | [time-zone: UK time], [transport: noisy train], [technology: lap-top, groupware software, unreliable communication channel], proposal, review procedure experience, people are available | Dinner, discuss proposal | Discuss the proposal using the distributed communication channel |
| Actor Z | [time-zone: UK time], proposal, people are available, experience, [technology: computer, groupware software, unreliable communication channel] | Get proposal accepted | Discuss the proposal using the distributed communication channel |

Like the social context tables the situation context tables are hierarchical in the way they describe organisations, groups and their constituent individuals in different tables. The decision to identify organisations, groups or agents depends upon the case being examined and through the identification of contextual differences that mainly exist between individuals that belong to the same group or groups that belong to the same organisation. In a case where a group has a high-level of involvement in an erroneous situation it is necessary to identify the group in a high-level context table and then identify the individual members in a separate low-level context table.

The type of data that needs to be organised relates to the following types of data:

1) Temporal context;
2) Spatial context; and
3) Personnel context.

The type of information that makes up the description of the ***temporal*** aspect of situation context consist of describing the dates and times that are present in each participant’s situation. In international and asynchronous communication, this information bears more relevance than in more local synchronous communication. The ***spatial*** information required for the situation context description includes information about the physical environments, the 'virtual' system environment and the objects that are available within it. The ***personnel*** information relates to the groups of people who are available to interact with, their abilities, their roles, their interests and the group size.

The situation context for each agent is described for each agent in terms of opportunities, interests and plans. The contextual elements that determine the opportunities that are available are listed and are organised into groups. These groups organise opportunities that are contextually similar in the way that they are either of the same type or are contained within each other. These groupings are distinguished by the square brackets ([…]) as seen in Table 4.7. These groupings can be nested to form a hierarchy of related items. Interests are harder to observe if they are not stated explicitly but can be identified either through their absence or interpreted through the opportunities that are available. Plans are distinguished through the identification of task sequences that contribute to the goal. Plans can be identified by identifying the middle level tasks that exist within the task analysis hierarchy.

*Local Interaction Context Tables*

The context table at the level of local interaction provides a structure for describing the context that each individual agent is working in. The context table at this level is complemented by the low-level tasks identified from the task analysis. The context table at the level of local interaction structures the information relating to agents, tasks, objects and events as seen in Table 4.8.

Table 4.8: Local interaction context table for the example case study

| Agent | Task | Tools | Events |
|---|---|---|---|
| Actor X | TASK 1 | Desk top PC, groupware software, communication channel, proposal | |
| Actor Y | TASK 1.1, TASK 1.3, TASK 1.4, TASK 2, TASK3 | Lap top, groupware software, communication channel, proposal, train | Office closes, connection failure in communication channel |
| Actor Z | TASK 1.1, TASK 1.3, TASK 1.4 | Desk top PC, groupware software, communication channel, proposal | |

Table 4.8 is a context table describing the contextual elements for the example case study. The table is organised according to the tasks, objects and events that are relevant to each individual agent. Many of these attributes can be obtained from the GTA models as described in Section 4.3.2.1. The tasks are indexed according to a hierarchical numbering system that reflects the hierarchy of tasks within the diagrammatic task model. A simple task analysis for the example case study can be seen in the following:

- TASK 1: Review proposal
- TASK 1.1: Connect to the Internet
- TASK 1.2: Present proposal
- TASK 1.3: Assess proposal against figures
- TASK 1.4: Discuss proposal
- TASK 2: Travel home
- TASK 3: Plan Dinner

The tasks in this context table reflect the tasks appearing at the lowest levels of the task analysis. The event concept was not seen in Mantovani's model of collaboration but was seen to be required when examining collaborative human errors to address the impact of technical failures and events that are outside of human control.

This section has described how the data can be structured using the groupware task analysis method and a series of context tables. The examples show how these tables can be completed and how they relate to each other and to the task analysis. At the level of social context procedures and policies are set (i.e. the review procedure) and how these affect the opportunities, interests and plans at the level of social context. Likewise the physical tools identified at the level of local interactions form the physical opportunities at the level of situation context. The task analysis can be used to determine between goals, plans and tasks at each level. The following section describes how creating these structures aids in error identification, classification and description.

### 4.3.3 Stage 3: The Application of the Classification and Description

This section describes how the classification can be applied to human errors in an erroneous situation and how the classification can then be extended to form a useful description for analysis. The effective application of the classification to human errors is a major factor in providing a useful tool for analysis. Applying the classification involves three main tasks consisting of:

1) Identifying human errors;
2) Applying the classification; and
3) Applying the contextual elements.

This section first describes how human errors are identified from the context tables and from knowledge of the erroneous environment. Secondly, the application of the classification is described and finally how the classification is extended to include contextual elements. This section describes how a notation is used to develop descriptions of collaborative human error.

#### 4.3.3.1 Identifying Human Errors

The first stage of applying the classification is to identify where an error has occurred. It was mentioned in Section 4.3 that errors can either be identified from a top-down perspective, at the level of social context, or from a bottom-up perspective, at the level of local interactions.

From a bottom-up perspective the identification of errors at the level of local interaction is followed by an examination of the local interaction context table to discover the agents, objects and tasks that are involved in the failure. These elements are then examined at the two higher levels of the model to identify the impact that they have on the human error. Through an examination of the elements in the higher contextual levels it is possible to determine the opportunities, interests and plans at the level of situation context and the goals, structures and history at the level of social context that relate to the erroneous situation. These elements can be examined to determine the role they play in the occurrence of the error.

From a top-down perspective errors are identified at the level of social context where a situation is seen not to meet a stated goal. The context tables are examined to identify, initially, the situation elements and then the local interactions that contribute to the occurrence of the error. A particular situation context is present through decisions made by an organisation or group to form structures or goals. Local interactions that are performed are dictated by the situation in which the agents are working and the opportunities made available to them.

#### 4.3.3.2 Applying the Classification

The second stage of applying the classification is to decide which contextual level the human error applies to and what concepts are involved in the conflict. Selecting an appropriate contextual level for a classification can be done through evaluating the agents, groups and organisations and the objects involved in the error.

In classifying human error at the level of social context it is important to identify the concepts of structures, history and goals that are associated with the error. If the contributing agent is an organisation then it is likely that the error is an error of procedure and is thus at the level of social context. Likewise, if the error occurs through a procedure being followed incorrectly or a lack of procedure then the contributing agent is the organisation conflicting with the agent's intention to achieve a goal. This, again, can be classified as a social conflict.

In classifying human error at the level of situation context it is important to identify the concepts of interests, opportunities and plans that are associated with the error. Identifying the objects available in the situation can assess opportunities. Examining a sequence of interactions can identify plans. Interests are harder to identify as they are a cognitive state of mind but can be implied from events such as conversation acts. If an identified error involves a physical or conceptual object present in the physical or 'virtual' environment and has an impact on a plan or interest of a group member then it is classified as a situation conflict. Likewise if a human error involves two or more individuals co-operatively working together using physical or conceptual objects which results in an erroneous situation it is classified as a situation conflict.

In classifying human error at the level of local interactions it is important to identify users, objects and tasks associated with the error. Human errors at this level do not affect other members of the group directly. It is only when an error at this level causes a conflict in opportunity, plan or conflict that they affect other group members and thus can be said to have a latent failure pathway in affecting other group members. Local interaction conflicts occur when an individual agent performs a human error in interacting with a physical or conceptual object.

A human error does not necessarily occur at one level but can evolve through two or three levels and thus is described by a series of error classifications. A human error that experiences this evolution is a ***compound conflict***. A classification of human error does not have to involve any collaboration and the same classification schema can be used to classify both single user and collaborative human error.

#### 4.3.3.3 Describing Human Error using a Notation

The notation that is used to describe human errors describes the human error in terms of the classification it applies to and the contextual element surrounding it. Identifying the contextual elements surrounding a conflict is essential in providing an effective human error description tool. In adding the context to a classification, information is being provided about the task, the users, objects and events that are involved in a human error. In the previous section it was shown how the contextual elements are used to derive classification levels for human error. This section describes how these contextual elements can be included in the classification to form an error description notation.

The style of notation used for the human error description is based upon the notation found in PUMA (Blandford and Good 1998a). The definitions for the notation are described using Backus-Naur Form (BNF) in the following:

| | | | |
|---|---|---|---|
| 1. | Error_Descriptor | ::= | Task_ID ":" (Conflict_A \| Conflict_B \| Conflict_C) |
| 2. | Task_ID | ::= | String |
| 3. | Conflict_A | ::= | 1*Agent "("Conflict_Item_A")" "-"*Agent "("Conflicting_Element_A")" |
| 4. | Conflict_B | ::= | 1*Agent "("Conflict_Item_B ")" "-" *Agent "("Conflicting_Element_B")" |
| 5. | Conflict_C | ::= | 1*Agent "("Conflict_Item_C ")" |
| 6. | Agent | ::= | Individual_name \| Group_name \| Organisation_name |
| 7. | Conflict_Item_A | ::= | Error_Type_A ":" Context_Element |
| 8. | Conflict_Item_B | ::= | Error_Type_B ":" Context_Element |
| 9. | Conflict_Item_C | ::= | Error_Type_C ":" Context_Element |
| 10. | Error_Type_A | ::= | "STR" \| "GL" \| "HIS" |
| 11. | Error_Type_B | ::= | "OP" \| "INT" \| "PL" |
| 12. | Error_Type_C | ::= | Classification "-" "Tool" \| Classification "-" "User" \| Classification "-" "Task" \| "TF-Tool" |
| 13. | Context_Element | ::= | Contextual_Item *[ "," Contextual_Item] |
| 14. | Contextual_Item | ::= | String |

The definitions described above describe how the notation is formed. The data for forming the notation is gathered entirely from the task analysis and context tables. The context items that form the context element are taken from the items and hierarchies identified in the context tables. The error types refer the classification elements of the collaborative human error classification (GL: Goal, STR: Structure, HIS: History, OP: Opportunity, INT: Interest, PL: Plan, TF-Tool: Technical Failure).The formations of the notation relate to four different error types. These are described using the following forms:

1. TASK_No.: Agent(ERROR_TYPE: Contextual_Element)-Agent(ERROR_TYPE: Contextual Element)
   *Describes an error where there is a conflict between different contextual elements belonging to different agents.*

2. TASK_No.: agent, agent(ERROR_TYPE: contextual element)-(ERROR_TYPE: contextual element)
   *Describes an error where multiple agents have the same context elements but the combinations of contextual elements are inappropriate for both agents.*

3. TASK_No.: agent(ERROR_TYPE: contextual element)-(ERROR_TYPE: contextual element)
   *Describes an error where a single agent is working in an environment where a combination of contextual elements is inappropriate.*

4. TASK_No.: agent(ERROR_TYPE: contextual element)
   *Describes a single user error at the level of local interactions.*

The first format relates to errors where two agents are conflicting with each other. The second format is when two agents are co-operating but still produces an erroneous situation. The third format is where a single user human error occurs at the two higher levels of the model. The final format is for describing local interaction conflicts. The contextual elements are added to the notation as they appear in the context table or according to the grouping they relate to (e.g. “technology: communication channel”). The contextual elements do not have to be stated in any particular order. Examples of these error descriptions for the example case study can be seen in the following:

**Erroneous situation: Review proposal**

1. TASK 1: Actor X(GL: Get proposal accepted)-Actor Y(STR: Anniversary)
2. TASK 1: Actor Y(GL: Discuss proposal)-Y Family(HIS: Forgot last years anniversary)
3. TASK 1: Actor Y(GL: Discuss proposal)- Y Family(GL: Celebrate anniversary)
4. TASK 1: Company A(GL: Get proposal accepted)-Company B(STR: Time Zone)
5. TASK 1: Company B(GL: Discuss proposal)-Company A(STR: Time Zone)
6. TASK 1: Actor X(PL: Discuss the proposal using the distributed communication channel)-Actor Y (OP: Mislaid the proposal)
7. TASK 1: Actor X(PL: Discuss the proposal using the distributed communication channel)-Actor Y(INT: Dinner)

8. TASK 1: Actor X, Actor Y, Actor Z (PL: Discuss the proposal using the distributed communication channel)-(OP: Technology: unreliable communication channel)
9. TASK 1: Actor Y(PL: Discuss the proposal using the distributed communication channel)-(OP: Transport: noisy train)
10. TASK 1: Communication channel (TF-Tool: Connection failure)
11. TASK 1: Actor Y(KB-Task: Mislaid proposal)

The above error description describes the collaborative human errors that contribute to the difficulties in reviewing the proposal in the example case study. Error descriptions 1 through to 5 describe how the erroneous situation was contributed to by social conflicts. These errors include the contribution of Actor Y's anniversary and how he forgot it last year and the contribution of the different time zones. Error descriptions 6 through to 9 describe how the erroneous situation was contributed to by planning conflicts. These errors include the diminished opportunity through the mislaid proposal, the physical conditions of the train and the unreliable communication channel and the inappropriate interest for the plan caused by the importance to Actor Y of celebrating his anniversary. Finally, errors 10 and 11 describe the errors of local interactions. These include the technical failure presented by the unreliable communication channel and the act of mislaying the proposal that meant that Actor Y did not have the relevant knowledge to perform the task.

This description of collaborative human error and the context it occurs in provides a structured tool for analysis. Conducting this analysis is described in the next section of this chapter.

### 4.3.4 Stage 4: Classification Analysis

The analysis of collaborative human errors that occur in a situation can take many forms depending on what the aim of the analysis is. Although the analysis of human error was not an aim of this research it is still possible to suggest how the approach can be used for suggesting recommendations for changes in procedure or the redesign of the human machine interface. The common aims of human error analysis are in predicting human errors, reducing their occurrence and identifying the causes of human error. This section gives a description of how an analysis can be conducted.

The description formulated in stage three of the application provides a structure that facilitates analysis. The structured approach allows the data provided within a description to be combined to allow the analysis of tasks, objects, agents and events and their relation to each other in an erroneous situation. The principle of the analysis facilities provided by the notation is that searches can be conducted for erroneous actions involving one or more of the contextual elements. The success of these searches will be determined by the consistency in the human error descriptions. By conducting these searches the following analysis types can be conducted:

1) The frequency of a human error using a specific object;
2) The frequency of an error involving a certain group member;
3) The effect that events have on human error;
4) The effect a group member has on a task using a specific object;
5) Identifying patterns in error descriptions; and
6) Identifying the causal pathways of a human error.

This is not a complete list but is an indication of the potential analysis capabilities of the classification model through the frequency of contextual elements and the identification of patterns within the description. The results of the analysis can be used to suggest recommendations and design changes.

By examining the frequency of contextual elements appearing within the error descriptions for the erroneous situation it is possible to examine the level of impact that each contextual element has to identify significant influencing factors. In many cases this data can lead to recommendations for changes in processes and redesigns of human machine interfaces. Frequency can either be measured of individual contextual elements such as agents or on combinations of items such as agents and tasks.

In some cases the analysis will identify influencing factors that cannot easily be changed because of the uniqueness of the situation. This is mostly apparent at the level of social context and may include things such as laws and regulations, people's attitudes and beliefs. Although these can not easily be changed or factored into design it is still important to recognise that they exist.

An analysis can also be conducted by making alterations to elements in the human error description. This can be used to show what would happen if a certain human error did not occur and can indicate the amount of impact that certain elements have on the erroneous situation.

The research in this thesis also indicated that patterns exist in the error descriptions in terms of the error classifications that make up the error description and the type of error under examination. Patterns also existed in the sequence of error descriptors forming the error description. Identifying and understanding patterns in error descriptions could potentially be used for error prediction and risk assessment.

In analysing the cause of an erroneous environment it has been argued that there is no absolute cause for a human error as the interpretation of the cause will depend on the purpose of the inquiry (Senders and Moray 1991). The cause and effect can be seen at any of the three contextual levels depending on the purpose of the analysis. The notation produced allows an analyst to follow a causal path through the three levels.

This research has not examined the full analysis capabilities of this collaborative approach to human error. Further work needs to be conducted to examine this area further.

## 4.4 Summary

This chapter has presented a classification model of collaborative human error and has described a possible framework of techniques that can be used for its application. These elements were developed through a three-phase research process including reported and observed case studies that could be studied in relation to collaborative human error. These studies resulted in a model that offers new definitions for collaborative human error, defines the scope of study, demonstrates how a human error evolves through the different levels of context existing in collaborative systems and defines a high-level classification system that can be used for their analysis.

The classification arose from the model by examining the relationships between the elements of the model and how they can interact with each other and with themselves to create an erroneous situation. The classification provides an approach for classifying erroneous actions at the three levels of the model and clear distinctions between each classification type have been made.

Chapter 5 describes the three-phase approach adopted for the development and evaluation of the model, classification and application approach in this research. The chapter describes the case studies that were studied for each phase, why they were selected and what the objectives of the studies were.

Chapter 6 and Chapter 7 describe each phase in more detail in relation to how the classification model was applied and in terms of how they contributed to the development of the classification model in this research. Chapter 6 describes the paper-based case studies and Chapter 7 describes the observed case studies.

# Chapter 5

# 5 The Research Approach

Chapter 4 described the classification model for collaborative human error. The chapter also describes an application framework that was used in this research to provide a structured approach by which the classification model can be applied. This chapter describes the approach that was undertaken to develop and assess these elements. A combination of case studies and observation were used within a three-phase research approach for the development and validation of the classification model.

The purpose of this chapter is to provide an overview of the research method adopted in this research. The chapter does not describe the impact that the research phases have on the development of the model or classification. Phase 1 was described in Chapter 3 and is summarised in Chapter 6. Phase 2 and 3 are described in detail in Chapter's 6 and 7 respectively.

The development and validation was undertaken through a process of case studies and naturalistic corpus gathering. Two paper-based case studies were used during this research. Observation or naturalistic corpus gathering was conducted to identify naturally occurring errors. This was conducted through experimental sessions conducted as part of the observed case study and of other experimental scenarios.

This chapter begins by firstly giving a description of available approaches for the examination of human error in collaborative systems. This is followed in Section 5.2 by a description of the three main phases conducted for the development and validation of the classification model presented in this research. Each phase is then described in the remaining sections by giving an overview of the content within each study, a description of why it was chosen, how it was used and what the objectives were. The chapter aims to give an overview of the research approach adopted. More detailed descriptions of Phase 2 and 3 are given in Chapters 6 and 7 respectively.

## 5.1 Approaches to Human Error Research

The examination of human error and the behaviour witnessed in collaborative systems can be achieved using a number of different methods. This section identifies established methods adopted for the examination of human error.

In Reason (1990) five established approaches to investigating human error were identified. These approaches consisted of naturalistic methods or 'corpus gathering', questionnaire studies, laboratory studies, simulator studies and case studies.

- *Naturalistic methods or 'corpus gathering'* is perhaps the most established method of investigating human error used by psychologists and psycholinguists for well over 100 years. The method has, in the past, involved 'collecting, analysing and classifying' naturally occurring slips and lapses. However, the same approach can be used for examining human error on a larger scale such as those seen in Chambers et al. (1999);
- *Questionnaire studies* are a method for collecting information about a person's experience of human errors. Questionnaires have been used in industry to collect information about incidents that occur and involve a person filling out a form requesting the details of the incident. The process is used to capture information that may normally not be captured due to the minor consequences that result from the incident;
- *Laboratory studies* are referred to by Reason (1990) as being a powerful technique for studying underlying behavioural mechanisms involved in human error. When using laboratory studies the researcher attempts to deliberately cause particular error types under controlled laboratory conditions;
- *Simulator studies* use computer-based simulations of naturally occurring events and tasks to enable the study of human error whilst maintaining a certain level of control. This approach is relatively recent and has mostly been used in the aviation industry; and
- *Case studies* are studies of events or accidents that contain sufficient evidence regarding their circumstances. Case studies have recently become a popular method

for human error analysis especially in the field of computing (e.g. Bes 1997 and Beynon-Davis 1999).

In regards to collaborative systems, evaluation is especially difficult due to reasons such as the effect of personality, behaviour and social dynamics on group behaviour (Grudin 1987). Due to the lack of established evaluation techniques for collaborative systems, the resources available for the research and the novelty of its principles it was decided to use a combination of case studies, laboratory studies and naturalistic corpus gathering.

## 5.2 The Three Phases of Research

The classification model presented in Chapter 4 form an approach to human error analysis from a collaborative perspective. This forms the basis of the work conducted in this research. In addition to the classification model an application framework has been identified that allows the classification model to be applied in a structured way. This section describes how the classification model was developed and validated through a three-phase research approach. The three phases consisted of:

**Phase 1:** The **initial development of the model and classification** to create the fundamental concepts of a classification model that can be used for the examination of collaborative human error. This is described using an illustrative example of collaborative human error.

**Phase 2: Paper-based case studies**

A) The ***Kegworth Accident case study*** (AAIB 1990) explores the classification model in a real life example of a collaborative human error. This case study provides the opportunity for Version 1 of the classification model to be developed and tested.

B) The ***LASCAD case study*** (South West Thames Regional Health Authority 1993) develops the classification model further through its application using a framework of techniques commonly used in traditional human error techniques. This application framework provides a more structured and detailed application of Version 2 of the classification model. Version 2 includes the model, the classification and the application framework.

**Phase 3: Observed examples of collaborative human error**

A) ***Examples of errors*** *in a collaborative diagram building task* using groupware environments are used to examine the ability of the approach to examine low-level examples of collaborative human error as opposed to the larger scale examples identified above. This study uses Version 3 of the classification model and application framework to examine these error examples.

B) *Examples of errors from the* ***WitStaffs case study*** further validate the classification model in an observed case study involving collaborative human error. As previously, the examination of these error examples is conducted using Version 3 of the classification model and application framework.

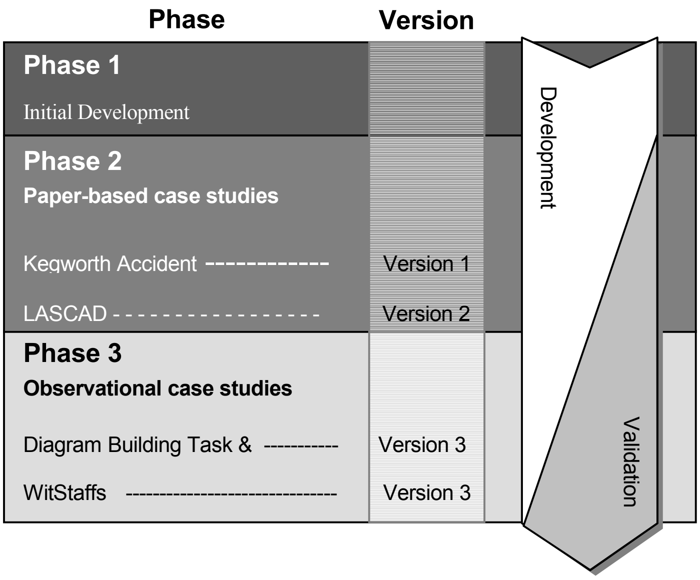


Figure 5.1: The 3 phases of the development of the classification model

Figure 5.1 shows how each phase of analysis relates to the development of the different elements of the collaborative human error approach. The following sections describe these phases in more detail by describing the events occurring within each case study, the purpose for it being carried out and the outcome.

## 5.3 Phase 1: Initial Investigation

The realisation that a high percentage of errors contained some element of collaboration in either their cause or through their consequences led to this examination of a collaborative approach to human error. Phase 1 involved examining the basic concept underlying the model of collaborative human error in relation to a simple example of collaborative human error.

### 5.3.1 The Initial Development of the Classification Model

The first phase of the research approach was to develop the fundamental concepts of the model of collaborative human error and perform an initial examination of these concepts on error examples.

#### 5.3.1.1 The Initial Development Approach

The initial development of a collaborative approach of human error was conducted in four main stages consisting of the following:

1) A literature review (described in Chapter 2) identified that collaborative aspects were not a major focus in traditional, behaviour based, human error approaches. The increasing use of collaborative systems led to the belief that it was important to consider issues of collaboration when looking at human error in these environments;
2) An examination of collaborative models was conducted to address this gap in regards to their applicability to the examination of human error. This examination was initially seen in Trepess (1997) and continued in Chapter 2 of this thesis;
3) The selected model of collaboration was developed to apply to the examination of human errors in collaborative environments. This was achieved by examining how an erroneous situation mapped on the model of collaboration (described in Chapter 3); and
4) The findings from this phase are initially tested by a simple application of the model on an illustrative example and the synopsis of the Daventry and Lambourne case studies (described in Chapter 3).

These four stages resulted in the fundamental concepts of the model described in Chapter 4. This model would be tested on a series of case studies and observed human error cases in Phase 2 and Phase 3.

#### 5.3.1.2 Objectives of the Phase

The model and classification developed in this phase proposes that human errors can be examined according to a model of collaboration as opposed to more traditional theories of behaviour. From a selection of collaborative theories Mantovani's model of collaboration was proposed as an appropriate basis for the model of collaborative human error. The objectives of this phase were as follows:

1) To assess whether Mantovani's model of collaboration was a viable choice for the examination of collaborative human error;
2) To develop Mantovani's model of collaboration to apply to human errors in collaborative environments; and
3) To propose a potential classification based on the model.

In order to describe the model an example of human error was used to illustrate an erroneous situation that included many of the elements identified from the background research and that existed in Mantovani's model. The illustrative example had the advantage of being constrained and controllable and protected from external factors complicating the purpose of the exercise. By studying the interactions that could occur in the example studies it was possible to examine the suitability of Mantovani's model as an approach for the examination of human error.

## 5.4 Phase 2: Text Based Case Studies

Phase 1 was conducted to test the basic underlying principles of the proposed model of collaborative human error. Phase 2 applies the classification model to case studies based on information reported in accident and incident reports.

Text based case studies were selected for Phase 2 for the following reasons as stated by Reason 1990:

1) Can yield valuable information about the circumstances leading up to an error occurring;
2) Where sufficient evidence is available regarding both the antecedent and the prevailing circumstances of a particular event or accident, there is the possibility to study the causal factors over an extended time scale that is difficult to achieve using other methods;
3) The details of the contributing factors to error can give a valuable insight into the limits of human performance that cannot be obtained from either the laboratory or from naturalistic observations; and
4) The studies contain an appropriate scope and complexity for evaluating theories and classifications of human error.

The following sections describe the case studies that were selected for the development and validation of the classification model in this research.

### 5.4.1 The Kegworth Accident Case Study

The Kegworth Accident case study (Appendix A) was used to test whether the fundamental aspects of the classification model can be applied within a real example of collaborative human error.

#### 5.4.1.1 Synopsis of the Kegworth Study

This synopsis has been derived from the synopsis in the Kegworth accident report (AAIB 1990).

The accident occurred on the 8$^{th}$ January 1989 near Kegworth in Leicestershire. The accident involved a Boeing 737-400, registration G-OBME, operating as a shuttle service between Belfast and London Heathrow. The aircraft had a crew of 8 people and there were 118 passengers on board.

A brief synopsis of the Kegworth Accident is that as aircraft, G-OBME, climbed through 28,300 feet the outer panel of one blade in the fan of the No.1 (left) engine detached. This caused a series of compressor stalls in the engine, shuddering in the airframe and smoke and fumes to enter the flight deck. Believing that the No.2 engine was malfunctioning, the crew throttled it back and later shut it down. In performing this action of recovery the shuddering in the airframe and the influx of smoke and fumes in the flight deck subsided which led the crew to believe that the emergency had been dealt with correctly. A diversion to East Midlands Airport was initiated and the aircraft was prepared for an instrument approach to land on runway 27. During the approach the aircraft experienced a severe reduction in power, followed by a fire warning 2.4 nautical miles (nm) from the runway. The aircraft struck a field adjacent to the eastern embankment of the M1 motorway and experienced a second impact on the west embankment of the motorway.

#### 5.4.1.2 Objectives of the Kegworth Study

The Kegworth Accident is the first time the classification model had been applied to a detailed example of human error. The previous phase addressed the development of the classification model and tested it on simple human error cases. This study established that the fundamental concepts of the model were applicable and that a potential classification could be devised from the concepts existing within the model. This initial case study in Phase 2 provided the first test of the classification model.

The Kegworth Accident case study was a critical point in assessing whether the collaborative approach to human error proposed in this research was applicable and potentially valuable. The objectives of this phase were as follows:

1) To examine the applicability of the model of collaborative human error in a well reported case study;
2) To perform initial tests to examine how the classification can be used to describe and distinguish between different types of collaborative human errors;
3) To examine the implications of taking a collaborative approach to human error; and
4) To identify problems with the model and classification and propose possible changes required to address them.

These objectives were addressed by taking a section of the Kegworth Accident scenario on which the model and classification was applied. The aspect of the Kegworth

Accident under investigation was the failure to correctly diagnose the fault. The classification is examined through its application to human errors occurring in the fault diagnosis task.

#### 5.4.1.3 Why the Kegworth Accident?

Phase 2 uses the Kegworth Accident case study to test the components of the classification and examine its ability to describe both collaborative and single user human errors. The study is also used to further assess the validity of the model for the examination of collaborative human error. The Kegworth Accident was selected for the following reasons:

1) The Kegworth Accident is a case well known for being attributed to human error.
2) The study is a popular case study for the examination of human error related research that indicates it is accurately and concisely documented;
3) The case study exhibits elements of collaboration in terms of the communication between the flight deck crew, the cabin crew and the air traffic control;
4) The case study exhibits many of the concepts considered within the proposed model of collaborative human error in terms of insufficient structures, a lack of communication and conflicting opportunities all contributing to the high-level failure; and
5) The study is an appropriate length and size for an examination of the classification model at this early stage of the research. It is not too large that it takes a long time to analyse but is sufficient to test the concepts of the classification model.

The application of the classification model to the Kegworth Accident case study and the outcomes are described in detail in Chapter 6.

### 5.4.2 The London Ambulance Service Computer Aided Despatch Case Study

This study uses the London Ambulance Service Computer Aided Despatch (here after referred to as the LASCAD system) case study (Appendix B) to examine the ability of the classification model to examine and analyse collaborative human errors. The method provided a structured approach that enhanced the ability to evaluate the classification model.

#### 5.4.2.1 Synopsis of the LASCAD Study

This synopsis has been derived from the synopsis in the LASCAD inquiry report (South West Thames Regional Health Authority 1993).

The LASCAD system was a brand new system intended to automate the human intensive task of despatching ambulances to patients. No computer-aided despatch (CAD) system offering as much automation as LASCAD had ever been used by any ambulance service in England. When the system was implemented on the 26$^{th}$ October 1992 a failure occurred that set the London ambulance service (LAS) into chaos. The main consequences of the LASCAD system failure occurred during the period of the night of Monday 26$^{th}$ October 1992 to the morning of Tuesday 27$^{th}$ October 1992. The failure in this example was not just a consequence of events on the 26$^{th}$ and 27$^{th}$ October but began much earlier during the initial development of the system. The development of the CAD system began in September 1991 by Systems Options Ltd (SO).

When the LASCAD system was implemented it was reported that the system was not complete nor were the operators properly prepared for its use. The failure became obvious when a flood of 999 calls swamped the operator's screen. This caused massive numbers of automatic alerts to be generated that stated that calls to ambulances had not been acknowledged. The system recorded a large amount of incorrect vehicle information that resulted in inappropriate ambulance allocation such as multiple ambulances attending the same incident. The system experienced a snowballing of problems. As more allocation errors were made fewer resources were available for allocation and the failure escalated with catastrophic consequences. It is estimated that the failure may have resulted in the deaths of 20 people though determining this is difficult.

A report by the Inquiry Team was written and published in February 1993 by the South-West Thames Regional Health Authority. The Inquiry Team consisted of highly experienced people in the ambulance service, computer audit and the Advisory, Conciliation and Arbitration Service (ACAS). The report was created based on evidence given by all groups and organisations associated with the system failure, the LAS and other ambulance services.

#### 5.4.2.2 Objectives of the LASCAD Study

The Kegworth Accident case study demonstrated the first application of the model and classification on well reported example of collaborative human error. The size of the Kegworth Accident case study and the level of detail undertaken was suitable for this early investigation. However, the study was limited in terms of the extent to which the model and classification could be applied and how it illustrated the implications of the approach. The LASCAD case study offered a much larger scope with which the model and classification could be applied. The objectives of this study were as follows:

1) To identify problems in the research and further develop the classification model to enable a more complete understanding of collaborative human error;
2) To increase the understanding of the issues involved in applying the classification model;
3) To develop a framework that can add a more structured approach with which the classification model can be applied;
4) To examine the application of the classification model and the changes made to it as a result of the Kegworth Accident case study; and
5) To get a clearer understanding of the potential issues and possibilities associated with taking a collaborative approach to human error.

These objectives were addressed by identifying two major elements in the LASCAD case study and examining them using the concepts within the classification model. The larger size of this case study meant that a more structured approach was required in organising the contextual data and describing the erroneous events that were identified. This led to the development of the framework described in Chapter 4.

#### 5.4.2.3 Why the LASCAD Case Study?

The LASCAD case study is a study that has already been extensively studied and analysed in previous human error research such as Beynon-Davies (1999). This case study was a valuable tool for the development of the research because it contained the following characteristics:

1) As with the previous study the LASCAD case study is a popular study for the examination of human error related research (Johnson 2001, Beynon-Davis 1995 and 1999 and Finkelstein et al. 1996) which indicates that it is accurately and concisely documented;
2) The case study involved a large amount of communication and collaboration both in terms of the use of the CAD system and through the course of its development;
3) The incident report contained valuable information about the history of the system development that had a significant impact on the system failure. This assisted in examining additional facets of the model not possible in the previous study;
4) The study contained a variety of different types of communication and collaboration that allowed the concepts existing within the classification model to be tested in many different ways;
5) The incident report was written in such a way that errors were easy to identify and contextual information was easy to extract; and
6) Contained information allowing the study of the interactions of the various causal factors occurring throughout the LASCAD development process and leading to errors in its use.

The application of the classification model to the LASCAD case study and the outcomes are described in detail in Chapter 6.

Phase 2 examined the classification model in relation to reported examples of collaborative human error. The following section describes observed examples of collaborative human error in Phase 3.

## 5.5 Phase 3: Observed Examples of Collaborative Human Error

Phase 2 was conducted to test the classification model in documented examples of collaborative human error. The paper-based studies were used because they contain a high level of detail and are well understood among the human error community. They also involved a low level of risk in regards to extracting the relevant information for the study.

Problems with using established case studies to evaluate the method are identified by Reason (1990) as including:

1) The information in accident and inquiry reports are concerned with attributing blame;
2) They tell a story that may be inaccurate or incomplete;
3) Accident and inquiry reports always contain less information than was potentially available; and
4) "…A written account has the effect of 'digitizing' what in the original was a complex and continuous set of 'analogue' events."

The approach in Phase 3 was to examine a corpus of human errors observed, first hand, in groupware use. The reasons for adopting this approach to examining collaborative human errors in this phase are described in the following points made by Reason (1990):

1) The approach has been used for well over 100 years as a tool for examining slips and mistakes;
2) Is regarded as a major stage for clarifying and validating a classification schema;
3) Portrays the richness and variety of the real-world phenomena of errors;
4) Given a large enough corpus the approach provides a reasonably comprehensive qualitative account of the available species of human error. The corpus of errors

collected in this research is not large enough to fully achieve this but provides a starting point; and

5) Offers a broad perspective on the mental landscape than can be obtained from necessarily focused laboratory studies.

The main disadvantage of corpus gathering is that the causal factors of a human error cannot be manipulated under experimental conditions to empirically examine and understand the causal chains leading to the circumstances of their occurrence. The scope of the research described in this thesis is concerned with understanding how these causal factors can be determined and described. This will allow the causal elements to be empirically examined in future research.

Conducting observational studies is expensive in terms of the amount of time and effort involved in setting up and observing real collaborative human errors. It was felt to be inappropriate to conduct an observational study until a more complete understanding of applying the classification model with the application framework was gained. Phase 3 advances the research by applying the classification model to observed examples of collaborative human error and so addresses the deficiencies of reported case studies that have been used up to this point in the research.

There were two sources from which the observations were made to collect the corpus of human errors. One source was a groupware experiment involving a collaborative diagram building task involving groupware technology. The second source was the WitStaffs project involving the set-up and use of an international groupware environment. Errors within this project were observed during the set-up of this environment and during an international conflict resolution study conducted as part of the WitStaffs project (Katz et al. 1999). These three sets of errors are described in the following sections and in Appendix D.

The following sections describe the two studies forming the two sources from which the corpus of collaborative human errors were observed, the objectives of the studies and how they were observed.

### 5.5.1 Error Observations in a Collaborative Diagram Building Task

This study looks at the classification model in relation to a corpus of small-scale examples of collaborative human error observed during a collaborative diagram building task (Appendix D). In this section an overview of these collaborative human errors is given but the examinations are not described in detail. A more detailed examination is described in Chapter 7.

#### 5.5.1.1 Description

The collaborative diagram building task was conducted as part of a groupware experiment. The purpose of the experiment was not to specifically manipulate the causal factors leading to the occurrence of human error but was to observe the occurrence of human errors in a groupware environment. The groupware environment was set up to provide a difficult environment for the users to complete their task and thus encourage the occurrence of human error. This was a study to observe errors in a complex environment. Observational studies, such as this have the benefit of showing users struggling with technical problems as they would occur without research intervention. This approach contrasts with the artificiality of laboratory study (Suchman 1987).

The task that was set for the diagram building study was for an instructor to give instructions to two other people on how to complete a partially completed Data Flow Diagram (DFD). The role of the instructor was to examine a completed data flow diagram and to construct and deliver instructions by email to the videoconference users on how to complete the diagram that they had on their screens as accurately as possible to the original. The instructor did not know how much of the diagram the builders had or if it was correct and the videoconference users at no time during the experiment saw the completed diagram. The builders had to work together to complete the diagram on their screens using the shared workspace based on the instructions received.

A number of errors were observed in these studies. In this research two typical errors are described and examined using the classification model. A brief description of the two errors to be examined is given in the following:

*Diagram Building Study*

1) ***The first error example*** involved the use of a combination of groupware tools consisting of email, video conferencing and a shared workspace. The error occurred due to the instructor omitting an item from the instructions. This omission led to confusion among the diagram builders causing an object on the workspace to be deleted (Appendix D2.1); and
2) ***The second error example*** involved an email being read out of the context in which it was written. An agent sends an email in response to a request from the instructor. A delay in the transmission results in the email being read in the context of a different task. This resulted in confusion between the agents in this erroneous environment (Appendix D2.2).

These errors occurred during a collaborative diagram building task in an experimental environment. The following describes how the data for these errors was gathered.

#### 5.5.1.2 Objectives of the Study

The evaluation in Phase 2 relied upon the data that was presented in the accident and incident reports and thus could be biased towards the conclusions drawn in these reports. In accident and incident reports, such as those used in phase 2, the emphasis is on attributing blame and the contents of these reports can be incomplete and inaccurate (Reason 1990). This section describes the objectives of this study.

In this study the case study is a new, previously unstudied example of an erroneous situation. The objectives of this study were as follows:

1) To address the problems of paper-based case studies identified by Reason by applying the classification model to observed examples of human error;
2) To contribute to a corpus of low-level errors that could be examined using the classification model;
3) To examine the application of the classification model and the changes made to it as a result of phase 2; and

4) To suggest changes to the classification model and application framework and suggest recommendations for future work in the area of collaborative human error.

These objectives were addressed by applying the classification model to the observed examples of human error observed in the diagram building study.

#### 5.5.1.3 How the Examples Were Observed

The purpose of the laboratory studies was to make observations of interactions with groupware environments and to capture the interactions that were made with the system and the communication occurring between the participants. This section describes approaches that were utilised for data capture in the two laboratory studies that consist of video, conversation logs, observation interviews and focus groups.

In the diagram building study camcorders were used to capture the interactions made with the groupware environment. Three camcorders were set up to record the interactions at each workstation. A single camcorder was pointed at the screen but also captured interactions with the mouse and the keyboard and also captured verbal communication. After the sessions the videotapes were played back and the interactions were logged in textual form. The problem with this approach was the large amount of information that was produced and that had to be reviewed. As each session was an hour long and contained three participants there were three hours worth of videotape to review for each session. In addition to this the problems of lighting, reflection and camera location affected the quality of the information recorded. In addition to the video recordings textual communication logs were made. In the case of the diagram building exercise textual logs were taken from the email inboxes subsequent to the session. These email transcripts were examined in combination with the video recording to place them in a temporal order and to place them in their context.

### 5.5.2 Errors Observed in the WitStaffs Case Study

The final study in Phase 3 describes the examination of this research in relation to observed examples of collaborative human error in the WitStaffs study. The WitStaffs case study (Appendix C) describes the set-up of an international groupware environment between Staffordshire University (England) and the University of the

Witswatersrand (South Africa). In this section an overview of these collaborative human errors is given but the examinations are not described in detail. A more detailed examination is described in Chapter 7.

#### 5.5.2.1 Description

The WitStaffs project involved the implementation and use of a groupware environment between the University of the Witswatersrand (Wits), South Africa, and Staffordshire University (Staffs), UK. A brief description of the WitStaffs project background, adapted from Thatcher et al. (2000) and the errors under examination is given below.

South Africa's recent apartheid history has left Wits with a wide discrepancy in the technological preparedness of black and white students. White students have been exposed earlier and more widely to information technology than their black counterparts. Exacerbating this discrepancy is the lack of access to computer facilities experienced by black students prior to attending Wits. Approximately 34% of students registered for the undergraduate module come from disadvantaged backgrounds both in their home and their school environment.

While every student at Wits has some access to a computer on campus, this access is limited with regards to time and software applications. Within the Psychology Department there are fifteen computers for over 1000 students. Therefore these computers are restricted for postgraduate student use only. These machines are not networked and are used solely for the purposes of performing statistics and writing documents. Undergraduate students have access to a communal computer facility with approximately fifty computers that service more than 4000 students. These computers are generally only used for email and word processing.

The collaboration between Staffs and Wits had been going on for two years, beginning with a project to examine the possibilities and difficulties of distance learning between the two universities (Thatcher et al. 1997). Since this initial project a TeamWave groupware environment was implemented allowing international communication between lecturers and researchers. This collaboration and the environment has been expanded to allow Industrial Psychology Masters students at Wits to experience the issues involved in CSCW through using the TeamWave environment to participate in collaborative tasks with students from Staffs.

An experimental session conducted as part of the WitStaffs project addressed the issues of contention resolution in distributed technologies. The TeamWave groupware environment was used to engage in real-time, synchronous discussions. In the experimental session participants were required to log onto the TeamWave workspace simultaneously and were allocated to one of two virtual discussion rooms, forming groups of five and four respectively. In each room they were asked to discuss and reach consensus on the topic: “The death penalty is an appropriate way of punishing violent crimes”. An administrator was present in each room to ensure that the discussion remained on track and to deal with any technical problems. After 2 hours of discussion the conversations were ended, whether the participants had reached a consensus or not. A focus group was held a day later to elicit information from the participants regarding their experience. The logged transcripts of the conversation were also used as part of the analysis.

*Errors in the Implementation and Use of the Groupware Environment*

1) *Setting up the environment and installing the groupware applications.* There were a series of errors involving the installation of the groupware at the University of the Witswatersrand;
2) *Conflict over tools in a shared workspace.* Two agents wanting to use two different tools but in the same location in the workspace; and
3) *Agents joining an incorrect workspace.* Two groups of students in two virtual rooms both performing the same task but in the first room there is little communication resulting in agents joining the second room.

These errors occurred during the implementation and use of the TeamWave workspace in the WitStaffs project. The following describes how the data for these errors was gathered.

#### 5.5.2.2 Objectives of the Study

In the Phase 2 evaluation the application of the classification model concentrated on social and situational factors. This was because the data to examine low-level errors was not available in the accident and incident reports. The application of the classification model in the Diagram Building study described in Section 5.5.1 concentrated more on low-level and situation factors. The amount of social context data available was limited because of the experimental nature of the study. The WitStaffs study aims to explore an erroneous situation where there are no constraints on the types of data that can be captured for the examination of collaborative human error.

In this study the objectives are mainly extensions of the objectives described for the previous study in Section 5.5.1.2. The objectives of this study were as follows:

1) To examine erroneous situations where all aspects of the model can be used to examine collaborative human errors;
2) To further addresses the problems of paper-based case studies identified by Reason by applying the classification model to observed examples of human error;
3) To further contribute to a corpus of low-level errors that could be examined using the classification model;
4) To further examine the application of the classification model and the changes made to it as a result of phase 2; and
5) To further suggest changes to the classification model and application framework.

These objectives were addressed by applying the classification model to the observed examples of human error observed in the implementation and use of the WitStaffs groupware environment.

#### 5.5.2.3 How the Examples were Observed

The WitStaffs project was initiated by a team of researchers belonging to the University of the Witswatersrand and Staffordshire University. The researcher at Staffordshire University is the author of this thesis and is the person who observed the erroneous events, gathered data and reported on the erroneous events as part of this study. The author of this thesis travelled to the University of the Witswatersrand to conduct this study. Data was gathered on the WitStaffs case study through a process of participatory observations, unobtrusive observations and through conducting interviews and focus groups with participants. The use of these techniques in this study are described below:

1) ***Participatory observations:*** The researcher was involved in setting up the collaborative environment, organising the training and running the experimental sessions;
2) ***Unobtrusive observations:*** The researchers observed the experimental sessions but did not participate except to perform troubleshooting actions;
3) ***Interview:*** After each of the experimental sessions each participant was interviewed individually; and
4) ***Focus Groups:*** Focus groups were conducted with all available participants to discuss the experimental sessions.

In the international WitStaffs laboratory studies text was the main communication channel for the subjects. Logs were taken of the communication and were examined in combination with notes made from observations. During the international laboratory studies a researcher was present in all workspaces being used. The researchers took the role of vicarious observers and at no time interfered with the exercise. During the observation notes were taken regarding interactions with the environment and regarding human errors that occurred. Subsequent to the sessions interviews and focus groups were held with the subjects to discuss issues identified through observations. Video recordings were not possible in the international laboratory studies because of the physical location of the researchers. Erroneous situations and contextual data were recorded throughout the study as reported in Appendix C.

## 5.6 Summary

This chapter has described the approach that has been adopted in this research to produce, develop and validate the classification model and the application framework described in Chapter 4. The chapter describes possible approaches for examining human errors and describes the three-phase process undertaken in this research that comprises case study and naturalistic corpus gathering approaches. Each of the studies is described in terms of providing a brief synopsis of each case, why it was chosen and its objectives. This provides an understanding of the approach adopted in this research and the process of classification model development undertaken.

The following chapters describe, in more detail, how this process influenced the development of this research. Chapter 6 describes the application and development of the model and classification on the paper-based case studies. Chapter 7 describes the application of the classification model on the observed examples of collaborative human error and how it improves the understanding of them.

# Chapter 6

## 6 The Development of the Classification Model

Chapter 5 described the three-phase approach that was adopted to develop and validate the classification model presented in Chapter 4. Each phase of the research involved the development of the model and classification. Phase 1 was described in detail in Chapter 3. This chapter describes Phase 2 of this research which involved two paper-based studies. The first of these studies applied the model and classification to the Kegworth Accident case study. The second study was a more detailed application of the model and classification to the LASCAD case study using an application framework. Phase 3 is described in detail in Chapter 7.

The studies in Phase 2 were as follows:

1) The Kegworth Accident is the first time the model and classification had been applied, in detail, to a documented example of human error. The Kegworth Accident case study was a critical point in assessing whether the collaborative approach to human error proposed in this research was applicable and potentially valuable. This study results in Version 1 of the classification model; and
2) The LASCAD case study offered a much larger scope with which the model and classification could be applied. This allowed a more complete understanding of collaborative human error and how it can be described within the model. The increased size of the case study meant that the model and classification were applied using a set of techniques to provide a more structured application. This study results in Version 2 of the classification model.

This chapter describes the development of the classification model that occurred during Phase 2. Section 6.1 describes the Kegworth Accident case study and then outlines the subsequent changes to the model and classification in Section 6.2. This is followed in Section 6.3 by a description of the LASCAD case study followed in Section 6.4 by a description of the changes to the model and classification. These two studies are described in regards to how the classification model was applied to each study, how each study led to changes to the research and how each study contributed to creating a more accurate understanding of collaborative human error.

## 6.1 The Kegworth Accident Case Study

The Kegworth Accident case study was used to test whether the fundamental aspects of the model and the classification could be applied to a real world erroneous situation.

### 6.1.1 Application of Model and Classification

The examination of the Kegworth Accident case study in this research involved four main stages. These include:

1) Identifying error components from the accident report;
2) Understanding the context in which the accident occurred;
3) Applying the classification to these error components; and
4) Using the classification elements to suggest conclusions about the accident.

These are described in more detail in the following sections.

#### 6.1.1.1 Identifying Error Components from the Accident Report

The first stage involved studying the section of the accident report that described the events leading up to the accident. During this study seven key error components leading up to the accident were identified.

1) **The Commander made a judgement of the situation based on his knowledge of the aircraft and its air conditioning system.** The Commander judged that the smoke and fumes were coming forward from the cabin and the air in the cabin comes mostly from the no.2 engine. This diagnosis could have been appropriate for other aircraft types that the Commander had experience of, however, it is flawed because the No.1 engine of a Boeing 737-400 also provides some air to the cabin;

2) **The reality of the situation, however, showed that smoke was experienced in the cabin some time after it appeared in the flight deck.** This failure may also have been contributed to by the increased workload presented by the autopilot being disengaged;
3) **There was no set procedure for the occurrence of a combination of vibrations and smoke/ fumes in the flight deck.** Procedures do exist for smoke in the flight deck and for vibrations in the flight deck but not for a combination of both symptoms. This means that the Commander and First Officer had to use their initiative when formulating the plan in this instance;
4) **The role change may have had an impact on the incorrect engine being identified as malfunctioning based on readings from the Engine Instrument System (EIS).** This is due to the fact that the First Officer had previously been occupied with flying the aircraft and had not familiarised himself with the dials on the instrument panel. The EIS system could also have been examined during a moment of temporary stability. It would also not be possible for him to make a comparison with dial states before and after the engine failure. Another possible reason for the EIS to have been misread might be because new instrument technology was being used that reduced the clarity of the instruments;
5) **The Commander, after analysing, the situation and determining that he believed the problem was with the no.2 engine, asked for confirmation of this from the First Officer.** The First Officer responded by saying 'IT'S THE LE ... IT'S THE RIGHT ONE.'. This shows some level of uncertainty as to the accuracy of the diagnosis. It is not clear what the First Officer saw that led him to reach this conclusion;
6) **In the cabin passengers and cabin crew were experiencing smoke, vibrations, unusual noises, unusual smells and many state that they saw fire coming from the No.1 engine.** Communication did take place between the Commander and the Flight Service Manager (FSM) who has responsibility for the cabin. The Commander calls the FSM up to the flight deck and asks 'DID YOU GET SMOKE IN THE CABIN BACK THERE?' The FSM replied 'WE DID, YES.' This question comes as a result of the Commander's plan to diagnose the problem by referring to the air conditioning system; and

7) **The Commander then broadcasts a message to the passengers informing them that there were problems with the right engine which produced the smoke, that it had been shut down and that they would be landing at East midlands Airport in 10 minutes.** This caused puzzlement among the passengers who heard the reference to the right engine but could see the left engine on fire. This discrepancy was not raised by either the cabin crew or the passengers.

These key erroneous events were the focus of the examination described in the following sections. Before these erroneous events can be fully understood in terms of the model of collaborative human error it is necessary to understand the context in which they occur.

#### 6.1.1.2 Understanding the Context in Which the Accident Occurred

In order to apply the classifications an understanding of the context in which the accident occurred was required (Appendix A2). This was discovered by grouping case study elements to the different elements existing within the model of collaborative human error. These groupings of contextual elements can be seen in Table 6.1 to Table 6.4. The first table describes the contextual elements for the organisations involved in the flight and the subsequent tables describe the context for the flight deck crew directly involved with the accident. Significant organisations in the Kegworth Accident include the aircraft operator (British Midland Airways Ltd), the aircraft supplier (Boeing Commercial Aeroplane Company), the Air Traffic Controller (ATC) towers (London ATC, Manchester ATC and East Midlands (Castledon) approach control) and finally the Civil Aviation Authority (CAA) who regulate aspects of aviation safety.

Table 6.1: Social context for the organisations involved in the flight

| Goals | Structure | History |
|---|---|---|
| **British Midland Airways Ltd.:** | | |
| **Goals** | **Structure** | **History** |
| The responsibilities of BMA are to provide the crew for the aircraft, to obtain aircraft from suppliers, maintain the safety of the aircraft under their control, to ensure that staff are fully trained, to provide rulebooks and guidelines of procedure and offer advice in the case of an incident. | BMA training procedures and resources | No history obtained from accident report |
| **Boeing Commercial Aeroplane Company:** | | |
| **Goals** | **Structure** | **History** |
| The responsibilities of the supplier are to ensure their aircraft are in full working order on delivery, to provide necessary training in the operation of their aircraft and to provide an aircraft flight manual. | Aircraft operations manual[1], quick reference handbook, maintenance manual, training. | The engine instrument system (EIS) technology had recently been changed. This change was from an individual hybrid electro-mechanical instruments to two solid state display units, one indicating the primary parameters and the other displaying the secondary parameters. |
| **London Air Traffic Control (LATCC), Manchester ATC, East Midlands (Castledon) approach control:** | | |
| **Goals** | **Structure** | **History** |
| The responsibility of air traffic control (ATC) is to direct aircraft around an airspace and maintain airspace safety. Within a controlled airspace a pilot must follow instructions from the ATC. When an aircraft is taking off or landing the aircraft flight is managed by controllers at the relevant airport. | *No structures identified from accident report* | No history identified from accident report |
| **Civil Aviation Authority (CAA):** | | |
| **Goals** | **Structure** | **History** |
| Responsibility to set safety standards and to ensure that they are maintained. This includes ensuring that adequate training is provided, that pilots are medically and physically fit, that aircraft are airworthy and that aerodromes are safe to use. The CAA sets the standards that all airline operators and air traffic controllers have to comply to. | Safety Standard Guidelines | No history identified from the accident report |

[1] In the accident report there are references to both an aircraft operations manual and a flight manual but there is no clear distinction as to the difference. In this examination are assumed to be the same thing and will be termed as the 'aircraft operations manual'.

The Kegworth Accident examination did not identify situation contexts or local interactions for organisations, as this information was not reported in the accident report. This is one of the drawbacks associated with paper-based case studies as reported in Section 5.4.

The following tables describe the contextual elements that apply to the flight deck crew. Other people involved in the accident include the cabin crew, the passengers and the air traffic control operators. Within the cabin crew group is a Flight Crew Manager who is responsible for the passenger cabin and liaising with the flight deck. Table 6.2 describes the social context for the flight deck crew.

Table 6.2: Table describing the social context of the flight deck crew

| **Flight Deck Crew:** | | |
|---|---|---|
| **Goals** | **Structure** | **History** |
| Review diagnosis<br>Fly the aircraft<br>Diagnose the fault<br>Diagnose the fault using air conditioning tool<br>Get confirmation that diagnosis was correct<br>Switch off correct engine | Training manual<br>Hierarchical structure of flight deck crew<br>Aircraft operations manual | Change in EIS technology |

Describing the social context involves identifying goals, structures and historical elements from the accident report. Structures are identified from rules, and regulations that are set by the organisations seen in Table 6.2. Historical elements can also be identified from the report though it is often not easy to differentiate between historical events that relate to the accident and those that do not. Goals are difficult to determine because, in most cases, they are not stated explicitly and have to be inferred from the text of the report.

Describing the situation context involves describing the opportunities, interests and plans of the agents. The Flight deck crew consists of two people which are the Commander and the First Officer. These two people have been treated as a single 'group' because they both have similar opportunities, interests and plans and little value was seen in separating them in this case. The situation context for the flight deck crew is described in Table 6.3.

Table 6.3: Table describing the situation context for the flight deck crew

| **Flight Deck Crew:** | | |
|---|---|---|
| **Opportunities** | **Plans** | **Interests** |
| **Physical opportunities**<br>The flying controls,<br>The engine instrument systems (EIS), and<br>The communication facilities.<br>**Conceptual opportunities**<br>Knowledge of Boeing aircraft operations manual,<br>Knowledge of Boeing quick reference handbook,<br>The Boeing training,<br>Increased workload, and<br>The BMA training.<br>**Collaborative opportunities**<br>Synchronicity,<br>Location,<br>Group size,<br>Planning time and<br>Information dependency. | Examine the EIS<br>Review stages of problem diagnosis<br>Use air conditioning system as indicator for fault diagnosis | Get to destination safely and on time. |

The process of identifying opportunities involved listing the physical, conceptual and collaborative elements available within the environment. As seen in the goal concept above, the process of identifying plans and interests is more difficult especially from reports such as the Kegworth Accident report. This is because these concepts are not specified explicitly in the Kegworth Accident report. The interests and plans can only be inferred from examining the interactions resulting from the identified opportunities. In order to discover the opportunities presented to the agents in the Kegworth accident each agent group is examined in turn.

The descriptions of the physical opportunities are simplistic, as a detailed description is not relevant at this level of context. A more detailed description would be relevant to a detailed analysis at level three where such an analysis was required. The conceptual opportunity list describes the flight deck crew knowledge of how to use the physical tools in the first list. A full list of qualifications achieved by the flight deck crew can be seen in Section 1.5 of the accident report (AAIB 1990). The collaborative opportunity concepts describe the collaborative situation in the flight deck. The flight deck seats two people, the Commander and the First Officer. Communication between these two is synchronous and co-located. All communication with other agents is also synchronous but is done initially using communication technology due to remote locations. Occasionally the Flight Service Manager visits the flight deck from the cabin allowing for local communication.

The Kegworth Accident was not studied in detail at the level of local interactions because the relevant data was not available from the accident report and was not required for this study. The local interaction elements can be seen in Table 6.4.

Table 6.4: Table describing the local interaction elements of the flight deck crew

| **Flight Deck Crew:** | | |
|---|---|---|
| **Tools** | **Users** | **Tasks** |
| Flight Controls<br>Engine Instrument System<br>Radio<br>Intercom<br>Autopilot | Commander<br>First Officer<br>Flight Crew Manager (FCM)<br>Air Traffic Control<br>Cabin Crew<br>Passengers | Fault diagnosis task,<br>Disengage auto-pilot,<br>Engine control tasks,<br>Radio communication tasks, and<br>Communication with cabin. |

Local interactions relating to tasks are difficult to determine from the accident report as they are not specified and can only be inferred at a relatively high level of abstraction. However, the elements of local interaction relating to tools and users can be obtained. Much of this data can be obtained from the examination of situation context. The list of opportunities provided at the level of situation context is refined to provide the physical tools that are used by the flight deck crew. Likewise, users can be identified through the examination of the higher contextual levels.

#### 6.1.1.3 Applying the Classification to the Error Components

Using the proposed model of collaborative human error and the understanding of the context in which the Kegworth Accident occurred it was possible to apply the classification to the key erroneous events identified from the accident report. The classifications of the 7 errors listed in Section 6.1.1.1 can be seen in Table 6.5. In performing the classification it was required to split some of the key erroneous events into sub errors which produce a total list of 18 error classifications.

Table 6.5: The classification of erroneous events in the Kegworth Accident

| No | Description | Classification |
|---|---|---|
| 1 | The Commander made a judgement of the situation based on his knowledge of the aircraft and its air conditioning system. The Commander judged that the smoke and fumes were coming forward from the cabin and the air in the cabin comes mostly from the no.2 engine. | Goal-Goal (GL-GL) by the commander<br>Goal: diagnose fault using air conditioning system<br>Goal: fault diagnosis |
| 2 | This diagnosis could have been appropriate for other aircraft types that the Commander had experience of, however, it is flawed because the No.1 engine of a Boeing 737-400 also provides some air to the cabin. | Plan-Opportunity (PL-OP) by the Commander<br>Plan: air conditioning, fault diagnosis tool<br>Opportunity: not relevant to aircraft type |
| 3 | The reality of the situation, however, showed that smoke was experienced in the cabin some time after it appeared in the flight deck. | Rule based error of the tool (RB-TOOL) by the Commander<br>Tool: air conditioning, cabin, flight deck, smoke in flight deck |
| 4 | This failure may also have been contributed to by the increased workload presented by the disengaging of the autopilot. | Plan-opportunity (PL-OP) by the Commander<br>Plan: examine air conditioning status<br>Opportunity: increased work load, switch off auto-pilot |
| 5 | There was no set procedure for the occurrence of a combination of both vibrations and smoke/ fumes in the flight deck. Procedures do exist for smoke in the flight deck and for vibrations in the flight deck but not for a combination of both symptoms. This means that the Commander and First Officer had to use their initiative when formulating the plan in this instance. | Structure-goal (STR-GL) by the FDC and the aircraft manufacturer (Boeing)<br>Structure of First Officer: under the command of the Commander<br>Goal of Commander: confirmation of air conditioning diagnosis |
| 6 | The role change may have had an impact on the incorrect engine being identified as malfunctioning. This is due to the fact that the First Officer had previously been occupied with flying the aircraft and had not familiarised himself with the dials on the instrument panel. | Skill based error of the tool (SB-TOOL) by the First Officer; or a<br>Tool: EIS system |
| 7 | The EIS system could also have been examined during a moment of temporary stability. | Knowledge based error of the tool (KB-TOOL) by the First Officer<br>TOOL: EIS, window of stability |
| 8 | It would also not be possible for him to make a comparison with dial states before and after the engine failure. | Interest-Opportunity (INT-OP) by the Commander and First Officer<br>Interest: compare EIS to previous state<br>Opportunity: EIS not monitored before role change |
| 9 | Another possible reason for the EIS to have been misread might be because new instrument technology was being used that reduced the clarity of the instruments. | Knowledge based error of the tool (KB-TOOL) by the First Officer<br>TOOL: EIS, Unfamiliar with new EIS system |
| 10 | Where the *history* is the change in EIS policy and the *structure* is a lack of change in the training policy | History-structure (H-STR) by BMA and the flight deck crew (FDC)<br>History: change in EIS technology<br>Structure: training manual |

| No | Description | Classification |
|---|---|---|
| 11 | the *plan*, in the first PL-OP classification, is to diagnose the fault and the *opportunity* is the reduced clarity of EIS | Plan-opportunity (PL-OP) by the First Officer<br>Plan: examine EIS<br>Opportunity: lack of EIS experience |
| 12 | the *plan* is to examine the EIS but the *opportunity* is reduced by the lack of clarity of the EIS display | Plan-opportunity (PL-OP) by the First Officer<br>Plan: examine EIS<br>Opportunity: EIS not conspicuous |
| 13 | The Commander, after analysing, the situation and determining that he believed the problem was with the no.2 engine, asked for confirmation of this from the First Officer. The First Officer responded by saying 'IT'S THE LE ... IT'S THE RIGHT ONE.'. This shows some level of uncertainty as to the accuracy of the diagnosis. It is not clear what the First Officer saw that led him to reach this conclusion. The diagnosis could have been influenced by the Commander's diagnosis due to his superiority in the form of an industrial conflict of work practice. | Structure-goal (STR-GL) by the Commander and the First Officer<br>Structure of First Officer: under the command of the Commander<br>Goal of Commander: confirmation of air conditioning diagnosis |
| 14 | In the cabin passengers and cabin crew were experiencing smoke, vibrations, unusual noises, unusual smells and many state that they saw fire coming from the No.1 engine. Communication did take place between the Commander and the Flight Service Manager (FSM) who has responsibility for the cabin. The Commander calls the FSM up to the flight deck and asks 'DID YOU GET SMOKE IN THE CABIN BACK THERE?'. The FSM replied 'WE DID, YES,'. This question comes as a result of the Commander's plan to diagnose the problem by referring to the air conditioning system. | Rule based error of the tool (RB-TOOL) by the commander<br>Tool: air conditioning, cabin, flight deck, smoke in flight deck |
| 15 | The *plan* is to discover whether there was smoke in the cabin but the answer from the FSM did not give enough information leading to an inappropriate *opportunity* for the Commander to make a diagnosis. | Interest-opportunity (PL-OP) by the Commander and the FSM;<br>Plan: To diagnose the fault using the air-conditioning<br>Opportunity: not enough information given by the FSM |
| 16 | The Commander broadcasts a message to the passengers informing them of problems with the right engine that produced the smoke, that it had been shut down and that they would land at East Midlands Airport in 10 minutes. This caused puzzlement among the passengers who heard the reference to the right engine but could see the left engine on fire. | Knowledge based (KB-TOOL) error by the passengers.<br>TOOL: Passengers had no knowledge of the aircraft or the terminology that describes it. |
| 17 | The *interest* of the Commander was in comforting the passengers but the *opportunity* presented in the cabin contradicted the Commander's statement. The cabin crew stated they did not hear the reference to the right engine. | Interest-opportunity (INT-OP) by the Commander, the cabin crew and the passengers<br>Interest: Reassure the passengers<br>Opportunity: Conflicted with Commanders comments |
| 18 | This discrepancy was not raised by anyone because their *interest* priority was not in diagnosing the fault even though they had the *opportunity* to do so. | Interest-opportunity (INT-OP) by the passengers<br>Interest: Not in fault diagnosis<br>Opportunity: Could see which engine was faulty |

Table 6.5 shows the classification for erroneous events occurring in the Kegworth Accident. This classification was achieved by studying the description of each erroneous event and classifying them by the contextual elements involved and where they relate within the model of collaborative human error. Some of the erroneous events

were split because the classification can only be used to classify errors involving 2 contextual concepts. Difficulties were experienced in distinguishing between goal, plan and task concepts in some cases.

This section described how the classification could be applied to the erroneous events identified in the Kegworth accident case study. The following section examines how the classification can be used to suggest conclusions about why the accident occurred.

#### 6.1.1.4 Using the Classification to Suggest Conclusions about the Accident

The classifications identified in the previous section were supplemented by the contextual data that decided the classification type. This formed more useful descriptions of each error. The classifications were then used as a tool to examine why the accident occurred by grouping errors according to common contextual elements. For example, grouping all the errors that involve the EIS or involving the flight deck crew. The error classification list in Table 6.6 groups all errors related to the failure to review the fault diagnosis task.

Table 6.6: Classification of events relating to the failure to review diagnosis

| **Classification** | **Description** |
|---|---|
| Conflict of Goal-Goal (GL-GL) by the FDC<br>*Goal of the FDC is to review the diagnosis but other goals are also presented* | Goal: review diagnosis<br>Goal: complete other tasks |
| Conflict of Plan-Opportunity (PL-OP) by the flight deck crew<br>*The opportunity for review is decreased by increased work load due to auto-pilot being switched off and re-programming FMS* | Plan: review stages of diagnosis<br>Opportunity: increased work load, switch off auto-pilot, re-programme FMS |
| Conflict of Plan-Interest (PL-INT) by the FDC and EMAC<br>*Plan to review previous actions but the interest of EMAC is to get information of the aircraft status* | Plan of FDC: review stages of diagnosis<br>Interest of EMAC: retrieve information on status |
| Conflict of Opportunity-Plan (OP-PL) by the external communicators and the FDC<br>*Interruptions to plan by radio communication from other aircraft who had no knowledge of emergency* | Opportunity of external communicators: no view of pilot actions<br>Plan of FDC: review diagnosis |
| Conflict of Interest-interest (INT-INT) by the FDC<br>*There was no interest in reviewing diagnosis as original diagnosis was assumed to be correct* | Interest: review diagnosis<br>Interest: belief diagnosis was correct |

It is fairly clear from the classifications in Table 6.5 that the air conditioning and the EIS system were major factors in the failure to diagnose the fault. This can be assumed due to the number of occurrences of these contextual elements in the error list. However, there was the opportunity for the flight deck crew to review the original decision. It is possible to view the classifications and contextual elements for the task of reviewing the diagnosis to examine why the diagnosis was not reviewed (Table 6.6).

From this description it is possible to ascertain that the EIS was not reviewed for a number of reasons. These include the increased workload presented by the communication tasks, re-programming the Flight Management System (FMS) and switching off the autopilot. There is also the possibility that the EIS was not reviewed simply because they were totally convinced that the correct diagnosis had been made from the air conditioning system.

## 6.2 Developing Version 1 of the Model and Classification

Some problems identified through this study have been indicated in the previous section. Some of the information described in the previous section has also originated from implementing some alterations during the case study examination. This section first describes the overall contribution to research then describes the issues and problems that were identified through the study. The section then describes the alterations that were made to the model and classification.

### 6.2.1 Addressing the Research Objectives

The previous section has described the examination of the model and classification in regards to the Kegworth Accident case study. The section began by describing how the model and classification were applied to the case study. From this examination a number of issues were identified with the model, the classification and the method by which it was applied. This section describes the contribution to the research by reviewing the objectives of the study specified in Chapter 5.

1) To examine the applicability of the model of collaborative human error in a reported study;
2) To perform initial tests to examine how the classification can be used to describe and distinguish between different types of human errors;

3) To examine the implications of taking a collaborative approach to human error;
4) To discover the limitations of the classification model; and
5) To identify changes needed to the classification model.

The Kegworth Accident case study was the first time the model and classification had been applied to a reported case study. The model relates to how the occurrence of collaborative human error is understood. Much of the understanding of collaborative human error is gained from applying the classification. The application described in this chapter illustrates that, with some changes, the model can more effectively be applied for the examination of collaborative human error. The model of collaborative human error stretches the examination of human error beyond the individual and considers the impact of other individuals, groups and organisations.

The classification was applied to erroneous situations identified in the case study. Although some difficulty was experienced in determining certain classification types the fundamental concepts were applicable. The classification could not only be applied to traditional human errors but could also classify situations not possible by traditional classification tools. It was identified that the classifications offered added value when they were accompanied by the contextual information they relate to.

At this early stage in the research it was not possible to gain a complete understanding of the implications of taking a collaborative approach to human error. Early indications suggested that valuable information could be gained about erroneous situations, their context and how individuals, groups and organisations contribute, either directly or indirectly, to their occurrence. The understanding of collaborative human error would improve and evolve through latter studies conducted in this research.

The study identified a number of problems and issues relating to the model and classification. These problems and possible solutions are summarised in Table 6.7.

Table 6.7: Problems and solutions resulting from the Kegworth Case Study

| ***Changes made during the Kegworth Study*** | | |
|---|---|---|
| **Change No.** | **Problems** | **Solutions** |
| 1.1 | Conceptual elements of the model at the levels of social context and situation context do not effectively describe human errors | Change the 'Action' element at the level of social context to 'Goal' and change the 'Goal' concept at the level of situation context to 'Plan'. |
| 1.2 | Problems of identifying concepts not explicitly stated in the accident report | Assumptions need to be made about contextual elements that are not explicitly referenced in the reports. |
| 1.3 | Distinguishing between organisation, groups and individuals was seen to be important but was not considered in the model. | Distinguish between organisations, groups and individuals during the organisation of the contextual data. |
| ***Changes to be implemented for future studies*** | | |
| **Change No.** | **Problems** | **Solutions** |
| 1.4 | Problems in organising the data so it can easily be used for classification | Context tables have been created and task analysis has been used to improve the organisation of contextual data. |
| 1.5 | Events are classified that would not traditionally be classified as human errors | Future studies of collaborative human error should not be restricted by traditional definitions of human error. A better understanding of what constitutes a collaborative human error is required. |
| 1.6 | There are problems in determining the level and type of classification appropriate for certain erroneous events | Clearer definitions of conceptual elements have been formulated. Task analysis hierarchies can also be used to aid the determination of classification level. |
| 1.7 | There are problems in the ability of the classification to meaningfully describe collaborative human errors | A semi-formal notation has been created to describe collaborative human errors. |
| 1.8 | There was a problem when dealing with errors involving contributions from automated technologies. | A classification type has been created that considers failures in technology. |

Table 6.7 describes the main problems if the model and classification and how these problems were addressed through implementing changes. Each of these problems and changes are described in more detail in the following sections.

### 6.2.2 Problems Identified Through the Research

Some problems identified through this study have been indicated in the previous section. Some of the information described in the previous section has also originated from implementing some alterations during the case study. This section first describes the issues and problems that were identified through the study. The following section then describes the subsequent changes that were made to the model and classification. This section describes the issues and problems experienced when using the model and classification to describe and provide an understanding of the context in which the Kegworth Accident occurred are described in Table 6.8.

Table 6.8: Table identifying the problems of the model identified from the Kegworth Study

| Problem No. | Description |
|---|---|
| 1.1 | Conceptual elements of the model at the levels of social context and situation context do not effectively describe human errors |
| 1.2 | Problems of identifying concepts not explicitly stated in the accident report |
| 1.3 | Problems distinguishing between organisations, groups and individuals |
| 1.4 | Problems in organising the data so it can easily be used for classification |
| 1.5 | Events are classified that would not traditionally be classified as human errors |
| 1.6 | There are problems in determining the level and type of classification appropriate for certain erroneous events |
| 1.7 | There are problems in the ability of the classification to meaningfully describe collaborative human errors |
| 1.8 | There was a problem when dealing with errors involving contributions from automated technologies. |

Table 6.8 gives a brief description of the problems of the model identified from the Kegworth case study. Each of these problems is described in the following.

***Problem 1.1:*** Describes the identification of a major problem in the products arising at each level of Mantovani's original model of collaboration. In Mantovani's model two of the concepts at each contextual level interact to form a product. At the level of social context structures and action interact to form a history. At the level of situation context opportunities and interests interact to form a goal and at the level of interactions users and tools interact to form a task. In the model of collaborative human error a failure to achieve a product at each level constitutes a collaborative human error.

The problem with this, in terms of Mantovani's model, is twofold; firstly, these products have no clear relationship to each other; secondly, at the level of social context history is not useful as a product, as far as human error is concerned, because it has no relationship to intent. An important aspect of human error is intention and it is not an intention of an individual, group or organisation to create a historical event rather it is something that just happens. This means that a new product is needed at the level of social context that reflects something that is intended. Structure is not a product but is something that is used to influence an action. An action in Mantovani's model is something that is produced from an evaluation of the situation and through the local interactions but is not something that comes as a direct result of structure or history.

***Problem 1.2:*** Identification of the difficulty experienced specifying concepts that were not described explicitly within the accident report. This problem mainly relates to the specification of goals, plans, interests and tasks. Partly the difficulty arises from a non-precise definition of the concepts which complicates the task of distinguishing between goals, plans, interests and tasks. It is especially difficult to distinguish between plans and interests. This is particularly the case when examining accident reports where the interest can only be inferred based on the opportunities and the realisation of a plan. The difficulty also arises because goals, plans, interests and tasks are psychological concepts that can only be inferred from the context and behaviour described in the report.

***Problem 1.3:*** The difficulty of distinguishing between organisations, groups and individuals. It is not always useful to examine every individual in an erroneous situation. This is especially the case when the contextual descriptions encompass multiple organisations as seen in the Kegworth Accident case study. In the early stages of examining the Kegworth Accident case study it became clear that there was an important requirement to make this distinction. Dealing solely with individuals results in a costly and time-consuming process. It can also be too focused detracting from the more abstract issues such as the impact of organisational policy on the erroneous situation.

***Problem 1.4:*** The difficulty of organising and structuring the information once it has been obtained or inferred from the accident report. This includes the organisation of elements to enable relationships to be detected and the specification of the levels of examination that are required in different instances. In this examination elements were collected and recorded in an ad-hoc fashion which was sufficient for a study confined to the examination of individuals but was clumsy when expanding the examination to include organisations and groups. It was also very difficult to determine when a sufficient level of detail had been achieved. This was not a major issue in the Kegworth

Accident case study as it had a confined scope and the level of detail was limited to that available in the accident report. However, it was foreseen that a more structured approach would be required for larger and less confined studies of human error.

***Problem 1.5:*** There was a problem that events were classified that would not normally be classified using traditional error classification mechanisms. This is not strictly a problem with the classification but is a problem in the way the model requires current understandings of what constitutes an error to be redefined. When examining human errors from a collaborative perspective the definition of what a human error is changes. For example, the fact that there was no set procedure for the occurrence of both vibration and smoke/ fumes in the flight deck (Error 5, Table 6.5) would be noted as a contributing factor but would not be included within a traditional error classification. The full extent of this change cannot be determined from this study but is reported throughout the remaining chapters of this thesis.

***Problem 1.6:*** The case study highlighted some important implications in terms of determining classification types and levels of certain errors due to some ambiguities existing between certain classification elements. The most significant of these consisted of the distinction between goals, interests and plans. These concepts were most affected by the adaptations to the concepts within Mantovani's original model resulting from phase 1. The ambiguity exists because they are all very closely related to each other in that a plan manifests itself as a result of a person's interest and a plan is conducted in order to fulfil a goal. That goal, in turn, arises from an assessment of interests, opportunities and possible plans that can be formulated to achieve it. This ambiguity led to the requirement for more clearly defined concepts.

***Problem 1.7:*** The classification, by itself, did not say a great deal about the actual elements that contribute to the erroneous situation. In order for the classification to be more descriptive and informative it required additional contextual information. There is limited value in specifying that an error is one type instead of another without describing the contextual elements that determine its classification type.

***Problem 1.8:*** The issue of automated technologies was discussed by (Woods 1996) and arose in this research through the involvement of the autopilot in the Kegworth Accident case study. The classification had no mechanism with which to deal with errors arising through the contribution of these technologies. The Kegworth Accident identified the concept of automated technologies and technical failure that can be a major contributing factor to accidents and incidents.

### 6.2.3 Changes to the Model and Classification

The previous section described issues that were experienced when applying the model and classification to the erroneous events occurring in the Kegworth Accident case study. These problems impacted on the ability of the case study and the application to generate a more complete understanding of collaborative human error. As a result of identifying these issues alterations were made to the model and classification and how they could be applied to the examination of erroneous environments. Some of these alterations were implemented in the Kegworth Case study and some were developed for application with the second case study in Phase 2. This section describes the alterations to the model and classification resulting from this case study as listed in Table 6.9.

Table 6.9: Table showing changes resulting from the Kegworth study

| ***Changes implemented during the Kegworth study*** | |
|---|---|
| **Change No.** | **Description** |
| 1.1 | Change the 'Action' element at the level of social context to 'Goal' and change the 'Goal' concept at the level of situation context to 'Plan'. |
| 1.2 | Assumptions need to be made about contextual elements that are not explicitly referenced in the reports. |
| 1.3 | Distinguish between organisations, groups and individuals during the organisation of the contextual data. |
| ***Changes to be implemented for future studies*** | |
| **Change No.** | **Description** |
| 1.4 | Context tables have been created and task analysis has been used to improve the organisation of contextual data. |
| 1.5 | Future studies of collaborative human error should not be restricted by traditional definitions of human error. A more structured approach is required to accommodate data relating to a more diverse understanding of human error. |
| 1.6 | Clearer definitions of conceptual elements have been formulated. Task analysis hierarchies can also be used to aid the determination of classification level. |
| 1.7 | A semi-formal notation has been created to describe collaborative human errors. |
| 1.8 | A classification type has been created that considers failures in technology. |

Each of the alterations in Table 6.9 is discussed in the following sections in relation to how it addresses each of the problems listed previously. The first section examines the changes implemented during the Kegworth study and the second section describes the changes to be implemented in the following study.

#### 6.2.3.1 Changes Implemented During the Kegworth Study

Throughout the study a number of changes were made to the model and classification during its application to the erroneous situation. These changes were either changes that were identified early in the study that were easy to implement or more significant changes required to effectively apply the model and classification.

*Change 1.1: Redefining Conceptual Elements*

To address the problem of products identified above some alterations were made to the concepts that occur at each level. At the level of social context a product that adequately fitted the requirements of an intention was a ‘goal’. A goal can be a product of structure and can arise from an evaluation of historical events. This decision resulted in a subsequent alteration at the level of situation context where the goal concept originally appeared in Mantovani’s model. At the level of situation context the product, again, had to meet the requirements of an intention, result from an evaluation of opportunities and interests. It was decided to have a ‘plan’ concept as the product at the level of situation context. A plan is seen to be a method, that can occur in an opportunity and that meets the interests of the people concerned, by which a goal can be achieved. The concepts at the level of local interactions remained unchanged.

This resulted in three products that were goals, plans and tasks that are all related in some way. Goals relate to the overall objectives of the collaboration, plans relate to methods that can be adopted to accomplish the goal and task relates to individual actions that are necessary to carry out the plan. A failure to achieve one of these products would constitute a collaborative human error. This problem was identified early in the study and this change was implemented during the examination.

*Change 1.2: Building Assumptions from Textual Data*

The nature of paper-based case studies means that not all the required information is available and has to be assumed. In the case of collaborative human errors interest concepts are difficult to determine from the text of the reports. This problem would be reduced through observational studies. However, the model and classification are in early stages of development and need to be refined and understood before being applied to observed examples of collaborative human error.

*Change 1.3: Distinguishing Organisations, Groups and Individuals*

Individuals can be grouped according to common elements that may be responsibilities, location and rank. In the Kegworth Accident this creates four main groups of people involved consisting of the Flight Deck Crew (Commander and First Officer), the Cabin Crew, the passengers and the air traffic controllers (air traffic controllers can be further grouped according to the airspace they control). Each group works for different organisations (discounting the diverse characteristics of the passengers) and there are organisations that are not directly involved in the accident but who have a significant impact on technology and the way it is operated. The distinction between organisations, groups and individuals has different implications at different levels of the model of collaborative human error.

The situation context for groups identified that different groups of people were working in different situations that provided different opportunities. Also each group and individual has different interests. The plans that they formulate are governed by the relationship between their opportunity and their interest. On the flight deck are the Commander and the First Officer. They both have the same opportunities in regards to the physical environment (though these may differ slightly through variations caused by seating position, i.e. line of sight, distance to controls, etc.). Opportunities may differ because of the conceptual difference between their rank or experience (in western airlines there is a shallow hierarchical structure adopted in the flight deck). They also have similar interests that are to reach their destination safely and on schedule. Due to the similarities between opportunities and interests it can be assumed that they have common goals and formulate common plans which can achieve them. These plans and goals are likely to differ from those of the ATC's and the cabin crew because of differences in opportunity and interest.

#### 6.2.3.2 Changes to be Implemented for Future Studies

The previous section described changes that were implemented during the application of the model and classification to the erroneous situation present in the Kegworth Accident. This section describes further changes that were implemented for the following studies in this research.

##### *Change 1.4: Structuring the Contextual Data*

In the Kegworth case study there was little structure facilitating the organisation of contextual information gained from the examination of the accident report. The Kegworth Accident illustrated the importance of context to describe collaborative human error. In order to make best use the contextual data task analysis and contextual data tables were constructed as part of a structured application framework to organise the information.

The context tables contain organisations, groups and individuals in the left-hand column and the contextual data relating to the concepts were organised in the remaining three columns. A table would be created for each contextual level.

In the early stages of the Kegworth Accident case study a task analysis was conducted to gain a more complete understanding of the events leading up to the crash. It became apparent during the case study that the task analysis could also be used to address some of the problems identified previously. The task analysis could be used to address both the problems of distinguishing between goals, plans and tasks and the problem of distinguishing between organisations, groups and individuals.

Most task analysis and cognitive modelling methods differentiate between goals, plans and low-level interactions in some way although some use different terminology. For example, the GOMS approach uses Goals, Operators, Methods and Selection Rules. Goals are synonymous with goals as defined in this research. Operators are similar to tasks in that they deal with low-level interactions between a human and an interface. Methods are similar to plans because they suggest a variety of approaches that can be adopted to achieve a goal. Finally, selection rules are similar to the evaluation between interest and opportunities that suggest the correct method, or plan, to use. Unfortunately, apart from (Van der Veer and Van Welie 1999, May et al. 2001 and Blandford and Goode 1998a) there are few studies focusing on producing cognitive models, such as GOMS, that are applicable to modelling behaviour in collaborative systems.

Task analysis approaches are commonly used within human error analysis methods (Kirwin 1992). The concepts of goals, plans and tasks in this research can be distinguished by examining the different hierarchical levels in a hierarchical task analysis (HTA). The lowest hierarchical level of abstraction can form the task concept. Collections of tasks at higher levels of an HTA form the plans and top levels of the hierarchy form the goals. Rules examine the opportunities and interests at the level of situation context to determine the appropriate plan to adopt to fulfil a goal. In this research Groupware Task Analysis (GTA) was used to model tasks and interactions occurring within the Kegworth Accident case study. Within GTA is also the ability to distinguish between groups and individuals.

### *Change 1.5: Redefining the Scope of Collaborative Human Error*

It was identified in the previous section that errors were identified in the Kegworth Accident that would not normally be defined as a human error. This is not a problem as such but means that collaborative human error stretches the boundaries of traditional definitions of human error. The Kegworth Accident is the first application of the model and classification to a real world scenario and is just the starting point of understanding the scope and occurrence of collaborative human error. What is clear from this study is that studies of collaborative human error should not be restricted by the confines of traditional human error definitions such as Bogner (1995) quoted in Section 1.1.1 in Chapter 1.

> *…an act, assertion, or decision that deviates from a norm and results in an actual or potential adverse incident. That incident may or may not eventuate in an adverse outcome. The norm which defines an error is consensually accepted by the constituents of the domain under consideration. An error may reflect a number of factors or may, be the final act in a series of contributing errors, i.e., a cascade of errors.*
>
> *Bogner 1995 (pg. A-24)*

### *Change 1.6: Refining the Concept Definitions for Classification*

This section addresses the problem experienced in distinguishing between certain contextual concepts. The concepts that were difficult to distinguish between consisted of goals, plans, interests and tasks. The problem of distinguishing between concepts was addressed by producing clearer concept definitions and by using task analysis to determine the correct level of classification. The original definitions for goals, plans and tasks, as specified in Chapter 3, are as follows:

1) **Goals:** High-level goals resulting from an evaluation of the structures and being affected by history,
2) **Plans**: A list of actions that can be achieved from an evaluation of the opportunities and interests present
3) **Tasks:** Actions that are performed by a user using a tool

These definitions emerged from the initial development phase but distinguishing between them became unclear when applied to the more detailed Kegworth study. The difficulty in distinguishing between plans and interests were not foreseen from the initial development and thus no definition was applied above and beyond the definition provided by Mantovani. Clarifying these definitions would help to improve the ability to distinguish between them. The new definitions of Mantovani's original concepts are clarified in the following:

1) ***Goals*** are the intentions of the parties involved in collaboration. Goals can apply to organisations, groups and individuals and can be formed on a number of levels. Goals can range from the mission statement of an organisation to the goal that leads to an individual action. A goal can originate from an evaluation of structures and

historical events or can originate from the selection of a plan set at the level of situation context.

2) ***Plans*** are a sequence of actions that are conducted to address a goal. In order for a plan to be classified it has to be initiated in an observable form. A plan is selected based upon an evaluation of the opportunities and interests present in the collaborative situation.
3) ***Interests*** are the internal cognitive factors that motivate a plan to be selected. A participant can have multiple interests competing for priority and control of the participant's attention to be activated within a plan (Mantovani 1996). An interest is not observable. In most cases they can only be assumed based on the present opportunities and the plans that are conducted or elicited from the participant in some way.
4) ***Tasks*** are individual actions or sequences of low-level interactions conducted as part of a plan. The manifestation of a task depends upon the tools that are available and the user that is conducting them. Tasks are not affected directly by any form of collaboration but can be affected indirectly through "plans" at the level of situation context.

In most cases the distinction between goals, plans and tasks can be achieved through the examination of the hierarchical levels appearing in a task analysis. They can also be distinguished by other contextual elements they conflict with to form the classification. In some cases a single error can be classified by all three concepts but differ in terms of the other contextual concepts they conflict with.

### *Change 1.7: Describing Contextual Data*

Applying the classification to the Kegworth case study was possible but there was limited value in the classification alone. Looking at the classification in relation to the contextual data that defines the classification type allowed a rich and well structured description of collaborative events that contributed to the accident. It was decided to try to combine the classification with the contextual descriptions using a semi-formal notation as part of a structured application framework. This notation was based upon the PUMA notation (Blandford and Goode 1998a and 1998b).

*Change 1.8: Addressing Automated Technologies*

The issue of automated technologies leads to the question whether automated technologies should be considered within the model and classification. Automated technologies did not have a major impact on the application of the model and classification on the Kegworth study. However, the autopilot indicated that they could potentially play a major part in the occurrence of collaborative human error and initiated an interest in how they can be addressed within the model and classification.

Automated technologies cannot have goals, interests or formulate plans and thus should not appear at the two higher contextual levels. They can, however, conduct tasks, control tools and be used by participants. This indicates that automated technologies should be dealt with at the level of local interactions. However, they do not fall neatly into either the tool or user concept but fall somewhere in the middle. This led to an additional classification type being added. Technical failures were added to Reason's skill, rule and knowledge based errors, which are applied to the concepts to form the classification of human error at the level of local interactions. The impact of a technology failure can have an impact on the opportunities present within a collaborative situation and this is likely to affect interests and plans. Automated technologies are examined in more detail in the following study.

This study indicated that the model and classification were applicable to real life examples of collaborative human error with some adaptations. These changes were implemented and were applied to the following paper based case study that relates to the LASCAD system failure. The LASCAD case study offered a larger scope by which a more complete understanding of collaborative human error could be achieved.

## 6.3 The LASCAD Case Study

The previous study in Phase 2 examined the application of the model and classification in regards to the Kegworth Case Study. This study identified that the model and classification were applicable and valid within the constraints of the case study. The study also highlighted a number of issues and alterations related to the model and classification that needed to be implemented and taken into account when applied in future studies. The following study describes the application of Version 1 of the classification model in regards to a larger case study.

### 6.3.1 Application of the Classification Model

In order to deal with the size and scope of the LASCAD case study a more structured approach was introduced to apply the classification model. A four-stage approach was devised that consisted of the following stages:

1) Data collection,
2) Organisation of the task and context data,
3) Formation of the classification descriptions, and
4) Analysis of the classification descriptions.

This four-stage approach follows a similar framework to that found in current approaches as seen in Table 2.4 in Chapter 2. The following sections describe how the classification model was applied to the LASCAD case study using this structured approach.

#### 6.3.1.1 Data Collection

The impact of the model on data collection is that it can be used to indicate the types of data that are required in order to perform an examination of collaborative human error. The current set of approaches available for data collection is common to all knowledge-based activities. These approaches include interviews, observations, literature reviews, focus groups and questionnaires. The LASCAD case study examination relied solely on information provided in the case report.

The LASCAD case report is a very long document that contains a lot of detail and spans a long time scale. Finding specific information and understanding the impacts and relationships between different events purely by reading the report is a complex and difficult task. The model of collaborative human error assisted data collection by dictating what information was required and once found indicated what that piece of information was in and where it applied in terms of the model (i.e. whether it was a goal, structure, opportunity, etc.).

#### 6.3.1.2 Organising the LASCAD Data

After determining what type of data is required it is important to organise it in a meaningful and logical manner in order to be able to derive useful information from it (Appendix B3). In the Kegworth Accident the contextual data was listed and grouped according to its level of context, its concept and who, or what, it applied to and task data was organised using a task analysis method (GTA). In the LASCAD case study a task analysis model was created and context tables (Change 1.4) described the contextual information applying to each level of the model. This section describes how this organisation was conducted.

A task analysis was conducted for high-level tasks identified in the LASCAD case study using GTA (Appendix B3.4). The task analysis generated a list of 6 high-level tasks that were involved in the system development, implementation and use. These tasks include:

TASK 1: Requirements specification,
TASK 2: Supplier selection,
TASK 3: Project management,
TASK 4: Systems testing and implementation,
TASK 5: Human resources and CAD training, and
TASK 6: The events of the 26th and 27th October 1992.

Within a study of collaborative human error each of these tasks would be examined to identify causes of erroneous situations arising within each and their contribution to the erroneous situation in Task 6. This segmentation enabled the LASCAD case study to be split into manageable segments. High-level elements of social context were identified for each of these six areas to give an overview of the context of the case study. These contextual elements are described in Table 6.10.

Table 6.10: Table listing overall social context elements of LASCAD case study

| Project area | Goals | Structures | History |
|---|---|---|---|
| TASK 1: Requirements specification | Improve LAS performance, produce requirements specs. | ORCON standards | Previous CAD project |
| TASK 2: Supplier selection | Select most appropriate supplier to deliver system | Requirements specification, RHA SFI, evaluation protocol, proposals, references | Experience of chosen supplier, experience of the supplier selection team, Andersen report |
| TASK 3: Project management | Provide project management, produce system on time & within budget | PRINCE, Apricot proposal, draft project plan | Project time scales, experience with PRINCE |
| TASK 4: System testing and implementation | Test system | Phased implementation | No history identified |
| TASK 5: Human resources and CAD training | Train users | Work Based Trainers (WBTs) | No history identified |
| TASK 6: Events of the 26th and 27th October 1992 | Despatch ambulances | LASCAD system | No history identified |

This context table gives an overview of the context applying to the overall case study. In this chapter elements of the supplier selection task (Task 2) are examined to illustrate the application of the classification model. The remainder of this section describes the elements of social context (as revised in Change 2.1), situation context and local interactions identified to be related to the supplier selection task.

The main organisations and groups involved in supplier selection were identified from the incident report. The elements of social context were then identified and were listed according to the organisations and groups that they apply to (Change 1.3). Table 6.8 stated that the high-level goal of supplier selection was to select an appropriate supplier to build the CAD (Computer Aided Despatch) system for the London Ambulance Service. The main elements of situation context included the requirements specification, the Regional Health Association Standard Financial Instructions, the evaluation protocol, the submitted proposals and the references for potential suppliers. The historical elements included the experience of the selected supplier consortium, the experience of the supplier selection team and a report generated subsequent to an investigation conducted by Arthur Andersen. These, and additional contextual elements are identified through a more detailed examination of the social context of the supplier selection task. Table 6.11 describes the elements of social context in relation to the organisations and groups involved in the supplier selection task.

Table 6.11: Table listing social context elements of supplier selection task

| Organisations | Goals | Structures | History |
|---|---|---|---|
| LAS management: | Improve performance, Ensure supplier is selected according to requirements and timetable | Requirements specification | Employed new Director of Support Services, Previous attempt at developing a CAD system, Previous bad performance record by LAS |
| LAS Board: | Improve performance, Select appropriate supplier, select proposal based on requirements, New CAD system to improve performance, Complete implementation in short time scale | Evaluation protocol, Requirement specification, Timetable, Reference review process | Previous bad performance record by LAS |
| Regional Health Authority (RHA): | Provide regulatory framework for procurement | RHA Standing Financial Instructions (SFI) | No history identified |
| Supplier selection team: | Advertise for suppliers, Select supplier who can meet requirements for project, Select supplier who can meet timetable for project | Evaluation protocol, proposals, references | Limited IT experience |
| Potential suppliers: | Win the contract | Requirements specification, Proposals | Experience of system development |
| Apricot: | Win the contract | Requirements specification, Apricot proposal | Previous bids with SO |
| System Options (SO) | Sub-contractor, software house | Apricot proposal | Previous bids with Apricot, experience in creating systems for emergency services |
| Datatrak: | Sub-contractor, Automatic Vehicle Location System (AVLS) supplier | Apricot proposal | No history identified |
| Auditors: | Confirm the propriety of the selection process | Audit report | No history identified |
| Arthur Andersen: | Advise action to be taken based on previous CAD development | Andersen Report | Review of previous CAD project |

Within each contextual level a table hierarchy can exist related to organisations, groups and individuals. For example, at the level of situation context the opportunities, interests and plans of the specific groups were described in one context table and those of the individuals were described in another. Table 6.12 and Table 6.13 give an example of this table hierarchy from Appendix B. Table 6.12 describes the situation context of the groups active in the supplier selection task.

Table 6.12: Situation context description of the supplier selection task

| Organisation, group or agent | Opportunities | Interests | Plans |
|---|---|---|---|
| Supplier selection team | Proposals, evaluation protocol, experience, SFI | Select appropriate supplier | Use evaluation protocol to evaluate proposals |
| Potential suppliers | Requirements spec., resources, experience, timetable | Win the contract | Write and submit proposal |
| Apricot consortium | Requirements spec., resources, experience, timetable | Win the contract | Write and submit proposal |
| Auditors | Audit report, proposals, requirements specification | Maintain procurement standards | Examine selection process |
| LAS Board | Proposals, RHA Standing Financial Instructions (SFI), references | Select appropriate supplier, improve LAS performance | Board meeting, use proposals, RHA Standing Financial Instructions (SFI), references for evaluation |

Table 6.11 describes the situation context for the supplier selection task. Many of the opportunities and plans are derived directly from the social context table (Table 6.11). Goals are either realised as plans or are conceptualised as interests. Structures and history form opportunities upon which plans and interests are formed. The identification of these elements from the context tables and from the task analysis (Change 1.6) makes it easier to distinguish between Goal and Plan concepts. However, identifying interests remains a problem. The supplier selection team represents a group of people. The situation context for this group is described in Table 6.13.

Table 6.13: Situation context description of the supplier selection team in supplier selection

| Organisation, group or agent | Opportunities | Interests | Plans |
|---|---|---|---|
| Contract analyst | Lack of IT experience, Proposals, evaluation protocol | Select supplier | Use evaluation protocol to evaluate proposals |
| Systems analyst | Experienced in IT and CAD systems, Proposals, evaluation protocol | Select supplier, being made redundant | Use evaluation protocol to evaluate proposals |
| Regional Supplies representative | Lack of IT experience, Proposals, evaluation protocol | Provide support for supplier selection | Use evaluation protocol to evaluate proposals |

As the examination of LASCAD entered into the details of the actual system failure on the dates of the 26$^{th}$ and 27$^{th}$ October the number of elements appearing within each segment of the table began to increase, especially in the opportunity fields. Many of these elements were related in that they were all parts of a larger element or were of a similar type and were grouped together using square brackets as seen in Table 6.14.

Table 6.14: Extract from situation context table relating to the 26th and 27th October 1992

| Organisation, group or agent | Opportunities | Interests | Plans |
|---|---|---|---|
| Operators | [Telephone, increased workload, calls, multiple call backs],<br>[CAD interface, reliability, speed, increased information, exception messages scrolling off screen, messages scrolled off screen, increase in two line summaries],<br>[Physical environment, room layout, few call takers] | Take calls, allocate ambulance, [correct system, provide information to other operators, read exception messages, increase system speed] | Input information into the CAD system, attend all messages, [recovery plan, clear exception messages, clear two line summaries, manual allocation] |

This grouping maintained an element of organisation within the contextual descriptions as the number of elements began to increase. The organisation also assisted in indicating important factors existing within the case that could have contributed to the system failure. For example, there are a great many opportunity elements listed that are grouped with the CAD interface. This indicates that the CAD interface was a major factor in the system failure.

Organising the contextual data for local interactions was difficult for the first five tasks as the required details were not always well stated or otherwise available from the incident report. Structuring the elements for local interactions for the events of the 26$^{th}$ and 27$^{th}$ October (Task 6) was possible.

Many of the elements existing in the local interaction table can be derived from the situation context table for this task. Tools could be inferred from the opportunities, tasks could be inferred from a more detailed task analysis of the plans and agents are derived from the groups and individuals involved in the collaboration. The context table for Task 6 can be seen in Table 6.15.

Table 6.15: Local Interaction Table for the 26th and 27th October

| ***Tasks*** | ***Agents*** | ***Tools*** | ***Events*** |
|---|---|---|---|
| TASK6.1: 999 call | Patients | Telephone | CAD slows |
| TASK6.2: operator answers | Callers | CAD | CAD lockup |
| TASK6.3: allocate ambulance | Operators | CAD interface | MDT lockup |
| TASK6.4: correct system | Ambulance crew | CAD status | Increase of 2 line summaries |
| | CAD | Ambulance | Workstation lockup |
| | Allocators | Ambulance location | |
| | | Radio | |
| | | Interface | |
| | | MDT | |
| | | MDT status | |
| | | MDT logon | |
| | | Workstation | |
| | | Exception messages | |
| | | 2 line summaries | |

The task breakdown in this table contains very little detail. The reason for this is that a detailed task analysis could not be performed due to the lack of information available in the incident report. A detailed task analysis was also not required in this study because the study aimed to focus on broader issues of collaboration affecting human error rather than a detailed analysis of actions performed by individuals.

Even at the level of local interactions agents can be referred to within groups. The reason, in this case, is that there were no references to actions of individual agents in the incident report. The agents can still be grouped at this level because the tasks and tools are the same for each agent within the group.

The identification of tools can be derived from the identified opportunities at the level of situation context. The tools are the physical elements that are used to perform a task. At the level the tools are broken down at a level suitable for the analysis. The relatively low-level of detail reported in the task analysis meant that tools could also be described at a fairly low-level of detail. A more detailed task analysis may require the tools to be broken down into their component parts.

An additional element has been added to this table that emerges from the GTA framework. This additional element is event and was added to further address the problem of failures in automotive technologies and other situations outside of human control such as natural disasters (Change 1.8). The need for this element arose out of the large number of failures that were contributed to by system failure and beyond direct human control. Even though these events were not controllable by the operators of the systems they are still classified as collaborative human error because of the human involvement in building them and in selecting an appropriate supplier to build them.

This section has described how the contextual elements related to the LASCAD case study are organised into context tables applying to each level of the model. This structure eases the examination of these contextual elements when classifying collaborative human errors. The classification of collaborative human errors is described in the following section.

#### 6.3.1.3 Formation of the Classification Descriptions

In the previous study it was identified that contextual information provided value to the classifications. A more structured approach was required for applying contextual data to error classifications. To address this issue a semi-formal notation was created (Change 1.7) based on PUMA (Blandford and Goode 1998a and 1998b) that included additional descriptive information to each classification occurrence. This section describes how this notation was formed and how it was applied to collaborative human errors identified in the LASCAD study (Appendix B4).

The notation was created based on the idea that a collaborative human error consists of two elements that adversely conflict with each other. These two elements form the two conflicting sides of the classification. Contextual information is added to both sides of the classification. The contextual data that is included in the notation includes the following:

1) The agents associated with each classification element, and
2) The task or tasks within which the event occurs.
3) The contextual element relating to each classification element.

This additional data is structured using the notation in one of four ways depending on the properties of the error. At the start of the study it was envisaged that errors could be described by the first and fourth structures. However, during the study it emerged that the other two structures were also required. The main differentiating factor between the structures is the agents and how the conflicts apply to them. In this research the term 'agent' includes organisations, groups and individuals. This applies through the remainder of this thesis. The four ways of structuring the notation are described in the list below:

1. TASK_No.: agent(ERROR_TYPE: contextual element)-agent(ERROR_TYPE: contextual element)
2. TASK_No.: agent, agent(ERROR_TYPE: contextual element)-(ERROR_TYPE: contextual element)
3. TASK_No.: agent(ERROR_TYPE: contextual element)-(ERROR_TYPE: contextual element)
4. TASK_No.: agent(ERROR_TYPE: contextual element)

The first format relates to errors where the elements of two agents are conflicting with each other. The second format is where two agents are co-operating but still produce an erroneous situation. In this case both agents have the same two contextual elements but they are incompatible for both agents. The third format is where a conflict occurs between the contextual elements for a single agent at the two higher levels of the model. The fourth format is for describing local interaction conflicts. The brackets are used to separate the contextual elements applying to each conflicting side of the classification.

This notation was used to describe the collaborative human errors occurring within the LASCAD case study. Table 6.16 describes the application of the notation to errors identified within the supplier selection task. The classifications and error descriptions for all the errors identified in the supplier selection task have been described in this section to describe how the notation is applied and how an entire erroneous situation can be described. Each error description is supported by extracts from the incident report to which they relate. This makes it easier to understand what the description is referring to. The identification of human errors for classification was not confined by traditional human error definitions (Change 1.5).

Table 6.16: Error Description for the Supplier Selection Task

| No | Description | Classification |
|---|---|---|
| 1 | 3031 The standing financial instructions also state that the lowest tender should be accepted unless there are "good and sufficient reasons to the contrary". | TASK 2: RHA(STR: SFI, lowest tender should be accepted)-LAS Board, selection team(GL: select appropriate supplier) |
| 2 | 3032 These standing instructions provide little qualitative guidance to procurement teams. The emphasis is very much on obtaining the best price. | TASK 2: RHA(STR: SFI, little guidance)-selection team(GL: select appropriate supplier) |
| 3 | 3033 The standing financial instructions also make reference to maintaining a list of approved suppliers from whom tenders should be sought. In the case of Command and Control Systems such a list did not exist. | TASK 2: RHA(STR: SFI, no list of approved suppliers)-LAS Board, selection team(GL: select appropriate supplier) |
| 4 | 3034 …Over the following weeks several meetings were held with prospective suppliers covering queries on the full specification and resolving other potential technical and contractual issues. These meetings were minuted by the project team and it is clear that most of the suppliers raised concerns over the proposed timetable – which was for full implementation by 8 January 1992. They were all told that this timetable was non-negotiable. | TASK 2: Supplier selection team(GL: Select supplier who can meet timetable for project)-potential suppliers(HIS: Experience of systems development) |
| | | TASK 2: LAS Management(PL: Implementation by 8 January 1992)-potential suppliers (OP: timetable) |
| 5 | 3035 …In order to appreciate why this timetable was set it is important to realise the pressures that the new LAS management were under to improve substantially the performance of the LAS. When the new management took over in 1990 they inherited a service where performance standards were extremely low and came nowhere near to meeting the nationally agreed ORCON standards for ambulance response. The Executive Board saw a new computer aided despatch system as the prime means of improving these standards. | TASK 2: LAS Management (HIS: Previous bad performance by LAS)-LAS Board (GL: Complete implementation in short time scale) |
| | | TASK 2: LAS Board, LAS Management (GL: Improve performance)-LAS Board (STR: Timetable) |
| | | TASK 2: LAS Board(PL: Build CAD system to improve performance) – LAS Management (OP: Timetable) |
| | | TASK 2: LAS Board(STR: evaluation protocol, only accept proposals meeting timetable)- selection team(GL: select appropriate supplier) |

| No | Description | Classification |
|---|---|---|
| 6 | 3036 …In their report Arthur Andersen state that the old project should be abandoned and that work should start towards the specification and acquisition or development of a new system. They also state that if a packaged solution could be found a budget of £1.5 million should be provided and a timescale from specification to implementation of 19 months would be appropriate. Their report also states that if a package solution cannot be found then these estimates should be significantly increased. In setting the timetable LAS management ignored, or chose not to accept, this advice. This Andersen report was never shown to the new Director of Support Services who would be taking direct responsibility for the new system. | TASK 1: Director of Support services (PL: Set requirements for CAD system)-(OP: did not know about the Andersen Report)<br>TASK 2: LAS Management (GL: Build a new system)-Arthur Andersen (HIS: Review of previous CAD project ) |
| 7 | 3040 It is clear from the actual procurement process that an inability to meet almost the total functional requirement or the proposed deadline would result in rejection of the proposal. In particular, it is evident that no proposal made the shortlist if the timetable could not be met. Therefore this factor actually had a higher ranking than was initially proposed. It is also clear that no specific weighting was given to the extent of supplier experience in Command and Control systems. | TASK 2: LAS Board (STR: Requirement specification, cost no more than £1,500,000)-potential suppliers(GL: win the contract) |
| 8 | 3042 Throughout this phase it was clear that LAS management and the project team had a proposed budget in mind, for the complete system, of around £1,500,000. There does not appear to be any rational process by which this figure was established, although it is possible that it was based on misunderstanding the original Arthur Andersen estimate (which was for a package system and excluded the AVLS elements). | TASK 1: RF: TOOL: LAS management team(Andersen Report)<br>TASK 2: LAS Management(GL: Complete system for under £1,500,000)-(HIS: Andersen Report) |
| 9 | 3044 In discussions with SO it is clear that they were initially unenthusiastic about bidding for this contract. They were resellers for Apricot and had bid with them unsuccessfully for a more basic system for the Cambridgeshire Ambulance Service. When the LAS requirement was advertised Apricot persuaded SO to propose to provide the CAD and mapping part of the system. | TASK 2: Apricot(GL: Submit proposal)-SO(HIS: previous unsuccessful bids with Apricot)<br>TASK 2: SO(OP: experience)-Apricot(INT: win contract) |
| 10 | 3045 The proposal from Apricot is very much a hardware led proposal. Compared with most of the other bids there is little detail on the application software proposed. This reflects very much the lack of enthusiasm at the time of SO to invest a lot of time in preparing a proposal in which they felt they had little chance of success. However, their proposal does state that they can meet the total requirement within the timescales proposed… | TASK 2: Apricot(PL: Write and submit proposal)-SO(INT: reluctance to submit) |
| 11 | …Their proposal also superficially suggests that they have experience of designing systems for emergency services. This is a true statement, but their expertise hitherto had actually been in administrative systems for such organisations rather than mission critical systems such as Command and Control. | TASK 2: LAS Board, selection team(OP: Apricot proposal, experience of developing systems for emergency services)- SO(OP: Experience, not in command and control) |

| No | Description | Classification |
|---|---|---|
| 12 | 3046 It should also be noted that the SO quotation for the CAD development was only £35,000 - a clear indication that they had almost certainly underestimated the complexity of the requirement ... It is worth noting also that, at a meeting between LAS and SO prior to contract award, it is minuted that SO were told that one of the reasons for abandonment of the earlier IAL system was the alleged inability of the software house to understand fully the complexity of the requirement. | TASK 2: SO(PL: Provide quotation for CAD development)-(OP: Knowledge of system complexity) |
| 13 | 3048 Amongst the papers relating to the selection process there is no evidence of key questions being asked about why the Apricot bid, particularly the software cost, was substantially lower than other bidders. Neither is there evidence of serious investigation, other than the usual references, of SO (or any other of the potential suppliers') software development experience and abilities. | TASK 2: LAS management team (PL: Application protocol, lowest tender accepted)-(INT: no attempts to discover why tender was so low) |
| 14 | 3049 The prime responsibility for the technical evaluation of the tenders fell upon the contract analyst and the Systems Manager. The representative from Regional Supplies was unable to evaluate the tenders on technical merits as her experience was in procurement in its most general sense rather than being specific to IT. | TASK 2: Supplier selection team (GL: Select appropriate supplier)-(HIS: Limited IT experience)<br>TASK 2: Supplier selection team (PL: select appropriate supplier based on their IT skills)-systems manager, Regional Supplies rep(OP: Knowledge of IT) |
| 16 | 3051 Thus a contractor and an arguably unsuitably qualified systems manager (who knew that he was to be replaced and made redundant) were put in charge of the procurement of an extremely complex and high risk computer system with no additional technical expertise available to them. This added to the high risk nature of the procurement. | TASK 2: Supplier selection team (PL: select appropriate supplier based on their IT skills)-Systems Analyst(INT: being made redundant) |
| 15 | 3056 Whilst the statement regarding SO's previous experience in designing systems for emergency systems is true it does not make clear that this experience is in less demanding administrative systems and does not closely parallel the much more complex LAS requirement. This statement although not questioned by the Board did give a false degree of comfort to the Board on the directly relevant experience of the CAD supplier. | TASK 2: LAS management team(OP: Apricot proposal, experience of designing systems for emergency services)-LAS Board(OP: not in command and control)<br>TASK 2: supplier selection team, LAS Board (RBTOOL: Apricot proposal) |
| 17 | 3058 During the selection process it is worth noting that certain other bidders raised questions that, with hindsight, had more significance than perhaps was obvious at the time. In particular, doubts are raised as to the ability of the communications system to cope with the potential load to be placed upon it, and of the reliability and state of readiness of the RIFS system. Both of these were prophetic as they were indeed problems that would affect the final implementation of the system. However, there is no evidence to show that these concerns were heeded at the time. There is no evidence that either of these potential problems were identified by the Apricot consortium. | TASK 2: Potential suppliers(HIS: experience of systems development, doubts of reliability)-LAS management (GL: improve LAS performance)<br>TASK 2: Potential suppliers (OP: requirements specification, doubts about reliability of system)-(PL: write and submit proposal)<br>TASK 2: selection team (INT: select appropriate supplier)-(OP: Apricot proposal, absence of concerns) |

| No | Description | Classification |
|---|---|---|
| 18 | 3052 Prior to making the formal recommendation to the LAS Board an "audit" of the selection process was carried out by the Systems Manager of the Scottish Ambulance Service … The main purpose of this "audit" was to confirm the propriety of the selection process and to ensure that adequate evaluation of the tenders had been undertaken. Overall this "audit" report endorses the team's decision, but it also states:<br>"… A value judgement has been made by the evaluation team, based upon valid technical reasons, that the circumstances in London make changing an existing package more risky than writing new software…". | TASK 2: LAS Board (GL: New CAD system to improve performance)-Auditors (STR: Audit report, review decision to build new system rather than changing existing package) |
| | | TASK 2: Auditor (PL: maintain procurement standards)-LAS management(INT: did not heed advice) |
| 19 | 3065 At the time of the procurement recommendation references were being sought on SO from certain of their existing customers. These references were very favourable as far as the technical quality of their work was concerned. However, the reference from the Staffordshire Fire and Rescue Service expressed some concerns over the continuing ability of the company to deliver results on time … both executive and non-executive members of the LAS Board have confirmed that they were not informed of adverse references having been received even though one of them was received by the LAS systems team on 24 May 1991, four days before the Board meeting at which the recommendation was endorsed. | TASK 2: LAS Management(GL: Select appropriate supplier)-LAS Board(STR: Reference review process) |
| | | TASK 2: LAS management (OP: concern into SO's ability)-(INT: no follow up of concern) |
| | | TASK 2: LAS management (OP: references, expressed concern over SO's ability to complete)-(PL: select appropriate supplier) |

Error 10 addresses SO's reluctance to be part of the Apricot consortium for the development of the LASCAD system. The contextual element of error 10, in terms of opportunity, is the experience that SO has in developing command and control systems. In terms of interest, the interest that Apricot has is in winning the contract. It is also important to place the human error in the context of the task being conducted. In this error example the task is the ‘supplier selection task’ (Task 2 from the task analysis). These situation context elements were added to the classification and expressed in the following format:

(TASK 2: Apricot(PL: Apricot proposal, bid for contract)-SO(INT: reluctance to submit))

In this case the error can be described using a single error classification. However, in many cases multiple classifications were required to describe a single collaborative human error. This can be seen in error 5 that describes the reasons for short timetable and its impact on the supplier selection task.

1) TASK 2: LAS Management (HIS: Previous bad performance by LAS)-LAS Board (GL: Complete implementation in short time scale)
2) TASK 2: LAS Board, LAS Management (GL: Improve performance)-LAS Board (STR: Timetable)
3) TASK 2: LAS Board(PL: Build CAD system to improve performance) – LAS Management (OP: Timetable)
4) TASK 2: LAS Board(STR: evaluation protocol, only accept proposals meeting timetable)- selection team(GL: select appropriate supplier)

The first error description describes how the previous bad performance recorded by LAS (History) led to the goal to implement the new CAD system in a short time scale (Goal). The second and third error descriptions describe how this short time scale affected the goal to improve performance, and the plan to use a CAD system to achieve this. Many potential suppliers did not foresee that they could meet this time scale (Error 4). The fourth error description describes that the goal of selecting an appropriate supplier was hindered by the timetable because so few proposals met the requirements of the evaluation protocol.

This section has described the structure of the notation and how it was applied to the supplier selection task in the LASCAD case study. The notation is effective at describing the errors occurring within the case study but is limited in terms of analysing the data to draw conclusions as to the causal effects of the system failure. The following section examines how the error lists can be grouped, filtered and reordered to aid in the analysis process.

#### 6.3.1.4 Using the Classification for Analysis

The final aspect of the application in this study is to be able to examine and draw conclusions from the error descriptions that are created through the previous stage. This examination can be conducted by examining error classifications that contain similar contextual data. For example they may involve the same agent, combination or agents, objects or events. By grouping classification elements in this way it is possible to assess the impact that a certain element has on causing the erroneous situation. The analysis of the LASCAD case study was conducted in three phases (Appendix B5):

1) **Phase 1:** The aim of the first phase is to perform a simple analysis to discover all errors made by a specific agent.
2) **Phase 2:** The aim of the second phase is to discover all errors which involve the relationship between two specified agents
3) **Phase 3:** The aim of the third phase is to discover the relationships between multiple high-level tasks.

After conducting phase 1 (Appendix B5.1) and phase 2 (Appendix B5.2) it was inferred that a large number of errors involved technology failures. Agents attempted to perform the set plans but these were hindered by the technology. This illustrates the importance of considering historical events such as the development process and management of the LASCAD system development. The analysis in phase 3 examines human error involving SO and the task of supplier selection.

The analysis in phase 1 highlighted that a majority of errors involved the CAD system. The development of the CAD system was the responsibility of SO. To discover why SO were selected to develop the CAD system a search can be done to extract all errors that involve SO in the supplier selection task. This produces the error list in Table 6.17.

Table 6.17: Table showing error descriptions relating to SO

| *Analysis of agent and task: SO and Supplier selection* |
|---|
| **Error Description** |
| TASK 2: SO(OP: experience)-Apricot(INT: win CAD contract) |
| TASK 2: Apricot(PL: Apricot proposal, bid for contract)-SO(INT: reluctance to submit) |
| TASK 2: LAS Board, selection team(OP: Apricot proposal, experience of developing systems for emergency services)-SO (OP: Apricot proposal, not in command and control) |

From this error list it can be seen that SO were reluctant to take part in the proposal mainly because of their lack of experience. The LAS Board and the selection team believed, from the proposal, that SO had experience in developing systems for the emergency services which was the case but not in command and control systems. This lack of experience is reflected in the following error list comprising of all instances of errors involving the CAD system.

Table 6.18: Table showing error descriptions relating to the CAD object

| *Analysis of object: CAD* |
|---|
| **Error Description** |
| TASK 6.2: operators(PL: input information into CAD)-(OP: CAD, poor interface, unreliable and slow) |
| TASK 6.3: allocator(PL: allocate ambulance)-(OP: CAD, inaccurate ambulance location) |
| TASK 6.3: allocator(TF-TOOL: CAD, collect ambulance data) |
| TASK 6.3: ambulance crew(OP: MDT, ambulance status)-allocator(OP: CAD, ambulance status) |
| TASK 6.3: allocator(TF-TOOL: CAD, identify all duplicated calls) |
| TASK 6.3: allocator(TF-TOOL: CAD, prioritisation of exception messages) |
| TASK 6.4: operators(INT: CAD, read exception messages)-(OP: CAD, exception messages scrolling off screen) |
| TASK 6.3: allocator(TF-TOOL: CAD, software resource allocation) |
| TASK 6.3 allocator(PL: allocate resources)-ambulance crew(OP: wrong, location, multiple vehicles to same incident) |
| TASK 6.4: operators(INT: CAD, correct system)-(OP: CAD, reliability, speed, increased information, exception messages scrolling off screen, messages scrolled off screen, increase in two line summaries) |
| TASK 6.4: operators(INT: CAD, correct system)-(OP: CAD, increase of information ) |
| TASK 6.4: operators(INT: CAD, clear exception messages)-(OP: CAD, exception messages scrolling off screen) |
| TASK 6.4: operators(PL: CAD, attend all messages)-(OP: CAD, messages scrolled off top of screen) |

The error list in Table 6.18 illustrates that the CAD system experienced failure in all tasks where it was used. The failures included bad interface design in terms of data entry, unreliability in terms of presenting incorrect and inappropriate information and an inability to facilitate error correction. These failures did not just have an impact on the operator and allocator agents but also had an adverse effect on the ambulance crew. The error list also shows that actions of the ambulance crew also had an impact on the CAD failure by not interacting properly with the MDT (Mobile Data Terminal) to provide correct ambulance status data.

This section has described the application of the classification for the analysis of collaborative human errors. This was possible through the previous stages of data collection, data organisation and classification. Through this case study a number of issues and lessons have been learnt about the classification model and the way in which it can be applied. The following section describes how this study contributed to the development of this research.

## 6.4 Developing Version 2 of the Classification Model

The previous sections have described the application of the classification model using a structured application. Similarly to the description of the Kegworth study, this section first describes the overall contribution to research then describes the issues and problems that were identified through the study. The section then describes the alterations that were made to the classification model.

### 6.4.1 Addressing the Research Objectives

Section 6.3 has described the examination of the classification model in regards to the LASCAD case study. The section began by describing how the classification model was applied to the case study. From this examination a number of issues were identified with the model, the classification and the method by which it was applied. This section describes the contribution to the research by reviewing the objectives of the study specified in Chapter 5.

1) To develop a more complete understanding of collaborative human error and how it can be described within the model;
2) To increase the understanding of the issues involved in applying the classification model;
3) To develop an application framework that can add a more structured approach with which the classification model can be applied;
4) To examine the application of the classification model and the changes made to it as a result of the Kegworth Accident case study; and
5) To get a clearer understanding of the potential issues and possibilities associated with taking a collaborative approach to human error.

The LASCAD case study applied the classification model using a structured application framework that was created and refined throughout the study. The LASCAD study was larger than the Kegworth study and offered many more opportunities to gain a more complete understanding of collaborative human errors. The application of the classification model and the creation of the framework all contributed to increasing our understanding of collaborative human errors and how the elements within the model can be used to describe them. The classification model was also refined based on the development of the application framework. The process of applying the framework and understanding the adaptations that were required to make it applicable to collaborative human errors highlighted a number of important points that needed to be included within the classification model.

The Kegworth study identified that a more structured approach was required to applying the classification model to erroneous environments. A framework for applying the classification model was developed during the case study. The development of this framework highlighted a number of important issues that needed to be addressed when applying the classification model and addressed the second and third objectives of this study. The application framework that emerged from this study shows a logical progression through the stages of data collection, data organisation, classification and analysis. This study highlighted the type of data that was required, how it could be effectively organised and how it could be applied to error classifications to form a structured notation that could be used to describe erroneous environments.

The Kegworth study described in the previous section resulted in a number of changes to be implemented in the LASCAD study. The application and impact of these is summarised in the following points:

1) The ‘Action’ element at the level of social context was changed to ‘Goal’ and the ‘Goal’ concept at the level of situation context was changed to ‘Plan’ (Change 1.1). This change made the model more applicable to human error by including an element of intention at each level of the model. The change led to the requirement for further changes as described in the following sections;
2) Assumptions needed to be made about contextual elements that are not explicitly referenced in the reports (Change 1.2). The LASCAD study was also based on documented information from the incident report and so assumptions about contextual elements remained an issue;
3) It was required to distinguish between organisations, groups and individuals during the organisation of the contextual data (Change 1.3). This was demonstrated in the

organisation of the contextual data at each level of the model and the classification process. The change led to a simpler study of a complex collaborative environment;

4) As part of a more structured approach to applying the classification model context tables were created and the use of task analysis was extended to improve the organisation of contextual data (Change 1.4). The creation of context tables and the extended use of task analysis increased the ability to understand the erroneous environment and aided in forming the classifications;
5) The LASCAD study of collaborative human error was examined using a much broader approach to human error (Change 1.5). The LASCAD study was a large and complex example of collaborative human error that illustrated many causal pathways. The study created a much more accurate view of what constitutes a collaborative human error and the scope of its examination;
6) Change 1.1 led to difficulties in distinguishing between Goals, Plans, Interests and Task concepts. Clearer definitions of these elements were formulated (Change 1.6). These new definitions and the use of task analysis hierarchies helped to distinguish between these concepts. Distinguishing between plans and interests remains difficult;
7) As part of the structured approach to applying the classification model a semi-formal notation was created to describe collaborative human errors (Change 1.7). The notation allowed the classification to be more descriptive. This assisted in improving the understanding of each error classification and their contextual elements; and
8) A classification type was created that considers failures in technology (Change 1.8). The LASCAD study included many errors arising from failures in technology. This demonstrated the need for this type of classification and its application in the context of a collaborative approach to human error.

Through the study a number of further issues were raised about the model, the classification and how they could be applied. These issues were addressed during this study and solutions were proposed. Table 6.19 summarises these points.

Table 6.19: Problems and solutions resulting from the LASCAD Case Study

| ***Changes implemented during the LASCAD study*** | | |
|---|---|---|
| **Change No.** | **Problems** | **Solutions** |
| 2.1 | Too many contextual elements being organised within the context tables | Grouping similar contextual elements, taking care to avoid duplication. |
| 2.2 | Limited ability to include automated technologies and events outside of human control within the context tables | Including the "event" concept to include actions performed by automated technologies and other events outside of human control |
| 2.3 | No linking between task analysis models and the context tables | Task analysis can be used to split large studies into manageable segments. Low-level tasks can be used to fulfil task concept at level of local interactions |
| ***Changes to be implemented for future studies*** | | |
| **Change No.** | **Problems** | **Solutions** |
| 2.4 | Incomplete understanding of collaborative human errors explicitly stated in the accident report | The study identified factors leading to a much more complete understanding of collaborative human errors and from developing the application framework. |
| 2.5 | Issues have arisen in regards to collaborative human error that are not included in the model. | New definitions have been proposed for collaborative human errors and changes were made to the model to address the improved understanding of collaborative human error. |
| 2.6 | Unexpected error types needing to be described by the notation | Notation was modified to accommodate these new error types. |
| 2.7 | Difficulty applying contextual elements to classifications due to inconsistent or incomplete data being held within the context tables. | Using a more structured approach to applying the classification can help to avoid duplication of contextual elements in context tables and to avoid ambiguous references. |
| 3.8 | It is unclear whether the agents that a classification applies to should be the creators, users or owners of the contextual elements that form the classification description. | At the level of social context an agent is responsible for the contextual element they are associated with by either being its owner or creator. At lower levels the agent is the user of the contextual element. |
| 2.9 | There was still a concern over the difficulty in distinguishing between plans and interests at the level of situation context. | The distinction between plans and interests became clearer through the events identified in the case study. These contextual elements were redefined based on these observations. |
| 2.10 | Error classifications conflict depending on the level at which organisations and groups are abstracted | The differences between the contextual elements associated with an individual and those associated with the group they belong to should be indicated through the relevant level of abstraction in the context table hierarchy. |

Table 6.19 describes the main problems if the model and classification and how these problems were addressed through implementing changes. Each of these problems and changes are described in more detail in the following sections.

### 6.4.2 Problems Identified Through the Case Study

The issues and problems associated with applying the model and the classification are described in this section. The section addresses problems and issues with the application of the model to build an awareness of how collaborative human errors occur, addresses problems with the classification and its ability to describe collaborative human errors. These issues and problems are listed in Table 6.20.

Table 6.20: Table identifying the problems of the model identified from the LASCAD study

| Problem No. | Description |
|---|---|
| 2.1 | Too many contextual elements being organised within the context tables |
| 2.2 | Limited ability to include automated technologies and events outside of human control within the context tables |
| 2.3 | No linking between task analysis models and the context tables |
| 2.4 | Incomplete understanding of collaborative human errors |
| 2.5 | Issues have arisen in regards to collaborative human error that are not included in the model |
| 2.6 | Unexpected error types needing to be described by the notation |
| 2.7 | Difficulty applying contextual elements to classifications due to inconsistent or incomplete data being held within the context tables. |
| 2.8 | It is unclear whether the agents that a classification applies to should be the creators, users or owners of the contextual elements that form the classification description. |
| 2.9 | There was still a concern over the difficulty in distinguishing between plans and interests at the level of situation context. |
| 2.10 | Error classifications conflict depending on the level at which organisations and groups are abstracted |

Table 6.20 gives a brief description of the problems of the classification model identified from the LASCAD case study. Each of these problems is described in the following.

***Problem 2.1:*** The first issue relates to the number of contextual elements being identified when examining the events of the 26$^{th}$ and 27$^{th}$ October. This occurs because the model has few contextual concepts by which identified elements can be grouped. In large cases such as LASCAD this can lead to large groups of contextual elements under each contextual concept. During the examination of the supplier selection task the context tables were easily capable of effectively organising the contextual data being identified from the incident report. However, during the examination of the details relating to the 26$^{th}$ and 27$^{th}$ October a large number of contextual elements were being identified. This situation involved agents situated in different locations having to use complex systems that were running incorrectly and whose interfaces were constantly changing. This produced long lists of elements occurring within the context tables that made it difficult to extract information from. The main contextual concept this concerns resulting from this study is the opportunity concept.

***Problem 2.2:*** This issue relates to the limited ability to include automated technologies and other events outside of human control within the context tables. This problem is an extension of the problem identified from the Kegworth case study relating to the inability to classify technical failures of automated technologies. The solution to this problem was to include an additional classification type at the level of local interactions that classifies technical failures. When creating this new classification type no consideration was paid to altering the context tables. During this study the classifications were formed by inspecting the context tables and how they contributed to conflicts identified from the task analysis.

***Problem 2.3:*** This issue relates to the lack of integration between the task analysis and the context tables. The task analysis in the LASCAD study highlighted the main tasks and areas for examination from the LASCAD case study. The sheer size of the LASCAD case study meant that understanding the entire context in which it occurred was difficult. Some form of contextual overview was required of the case study. Low-level interactions were not covered in any detail due to limited information existing within the incident report. However, it was foreseen that these would be important when identifying tasks at the level of local interactions.

***Problem 2.4:*** This issue relates to the incomplete understanding of collaborative human errors that still exists. The LASCAD case study has increased our understanding of collaborative human errors in a number of ways.

1) The case study included events occurring over a long period of time highlighting the important issue of error latency;

2) The study illustrated how multiple error descriptions were often used to describe a single erroneous event;
3) Patterns are emerging related to the evolution of collaborative human errors through the model;
4) Different types of collaborative human error were identified through applying the notation (described further in the following section); and
5) The application of the model to this study was conducted by using a top-down approach, examining the social context first then the situation context and finally the local interactions. Alternative approaches to applying the model could produce different results.

These issues need to be considered within the model of collaborative human error. These issues have emerged from this study and the Kegworth study. They are discussed further in terms of their inclusion into the model in Section 6.4.2.

***Problem 2.5:*** This issue relates to observations in collaborative human errors that were not covered in the current definitions of human error. The realisation that collaborative human errors do not occur in a single instance of time but occur over a period of time identified an element of collaborative human error that was not catered for using current human error definitions. Current human error definitions do not effectively include the elements that lead to or result from collaborative human error. These issues are fundamental aspects of what makes a collaborative human error.

***Problem 2.6:*** This point describes a problem that arose when attempting to apply contextual information relating to agents to the error classifications. The initial idea behind the notation was that agents would appear on both sides of the classification. This would illustrate how a contextual element of one agent would conflict with a contextual element of another agent to impede collaboration. However, this did not always prove to be the case. In many cases it was found that two conflicting elements applied to the same agent or agent group. This shows that the collaboration was not impeded by conflicting agents but by conflicting contexts. This can also apply in the occurrence of single user human errors. This meant that the agent concept only appeared on one side of the classification not both as originally thought. This indicated the presence of different types of collaborative human error that can be described within the classification.

***Problem 2.7:*** This point relates to a difficulty that was experienced both during the assignment of contextual elements to the classification and the re-organisation of the error descriptions during analysis. The problem was that inconsistencies and ambiguities existed in the way that contextual elements were identified and stated during the creation of the context tables. This meant that it was difficult to choose between similar contextual elements or elements that referred to the same thing when building the error description. The problem made it difficult to both create the error descriptions and to come to conclusions about the effect that contextual elements had on the erroneous situation. This difficulty led to the context tables being reviewed and amended.

***Problem 2.8:*** This point relates to how the contextual elements are associated with the agents that they relate to. Is the agent the creator, owner or user of the contextual element? The problem was especially apparent at the level of social context where an agent's only contribution to an erroneous situation may be to set a goal or create a structure that impacts upon the opportunities of agents directly involved in the situation. Is the structure or goal assigned to the user directly related to the incident or its creator? This problem did not arise during the Kegworth study due to its limited scope but became an important issue when applying the classification to a larger case study where it impacted upon the ability to trace historical contributions to an erroneous situation.

***Problem 2.9:*** This point relates to the concern that still existed over the difficulty in distinguishing between the plan and interest concepts at the level of situation context. The new definitions arising from the Kegworth Study helped in clarifying the difference. It was also decided from the Kegworth study that error classifications would only include the interest concept is that interest was specifically stated. However, occasions arose in the LASCAD study that meant an error classification had to include interest even though that interest was not specifically stated. The first occasion where this problem arose was seen in the following examples:

1) TASK 2: Auditor (PL: maintain procurement standards)-LAS management(INT: did not heed advice)
2) TASK 2: LAS management (OP: references, concern into SO's ability)-(INT: no follow up of concern)
3) TASK 6.4: operators(INT: CAD, read exception messages)-(OP: CAD, exception messages scrolling off screen)

The first two examples indicate clearly that a lack of interest contributed to the erroneous situation. In classifying these errors the evidence suggests that LAS Management should have been interested in the statements made in the audit report and the adverse comments in SO's references. No plans were formulated to follow up these concerns and so it was safe to assume that the classification included the interest rather that the plan concept. In the third example the opportunity presented by the CAD interface did not allow the interest to read the exception messages to be formulated into the plan. These examples show a clear difference between interests and plans that needs further examination.

***Problem 2.10:*** This point identifies an issue associated with grouping individuals when describing contexts in which they work and when creating error classifications. As a group there can be an overall goal or interest but the individuals within that group can have different levels of belief and interests. This issue arose in the Apricot consortium. As a consortium their goal was to win the contract to supply the LASCAD system. However, when the consortium is broken down to its individual contributors it becomes clear that SO are far less keen to submit the proposal that Apricot. This only becomes apparent when the group is split into its individual organisations. This highlights a risk that is taken when grouping agents to make classification more efficient.

### 6.4.3 Changes to the Classification Model

The previous section described issues that were experienced when applying the classification model to the erroneous events occurring in the LASCAD case study. The study highlighted a number of issues related to the model, the classification and the way in which they are applied. As a result of identifying these issues alterations were made to the classification model and how it could be applied to the examination of erroneous environments. Some of these alterations were implemented during the study, involved only an increased awareness of their existence or were developed to be applied during the case studies in Phase 3. This section describes alterations resulting from this case study as listed in Table 6.21.

Table 6.21: Table showing changes resulting from the LASCAD study

| ***Changes implemented during the LASCAD study*** | |
|---|---|
| **Change No.** | **Description** |
| 2.1 | Grouping similar contextual elements, taking care to avoid duplication. |
| 2.2 | Including the "event" concept to include actions performed by automated technologies and other events outside of human control |
| 2.3 | Task analysis can be used to split large studies into manageable segments. Low-level tasks can be used to fulfil task concept at level of local interactions |
| ***Changes to be implemented for future studies*** | |
| **Change No.** | **Description** |
| 2.4 | A much more complete understanding of collaborative human errors was gained from applying the classification model and from developing the application framework. |
| 2.5 | New definitions have been proposed for collaborative human errors and adaptations were made to the model to address the improved understanding of collaborative human error. |
| 2.6 | Notation was modified to accommodate these new error types. |
| 2.7 | Care should be taken to avoid duplication of contextual elements in context tables and to avoid ambiguous references. |
| 2.8 | At the level of social context an agent is responsible for the contextual element they are associated with by either being its owner or creator. At lower levels the agent is the user of the contextual element. |
| 2.9 | The distinction between plans and interests became clearer through the events identified in the case study. These contextual elements were redefined based on these observations. |
| 2.10 | The differences between the contextual elements associated with an individual and those associated with the group they belong to should be indicated through the relevant levels of abstraction in the context table hierarchy. |

Each of these alterations is discussed in the following sections in relation to how it addresses the problems that were listed in the previous sections. The first section examines the changes implemented during the LASCAD study and the second section describes the changes to be implemented in the following study.

#### 6.4.3.1 Changes Implemented During the LASCAD Study

Throughout the study a number of changes were made to the classification model during its application to the erroneous situation. These changes were either changes that were identified early in the study that were easy to implement or more significant changes required to effectively apply the classification model.

*Change 2.1: Grouping similar contextual elements*

The issue regarding the excessive number of contextual elements being identified mainly involved the opportunity concept at the level of situation context. This issue was tackled by grouping similar elements together. These groups were formed in two ways based upon the GTA framework for object concepts. Opportunity elements were grouped according to whether they are a sub-element existing within a larger object or whether they are similar in type.

*Change 2.2: Including the "event" concept to include actions performed by automated technologies and other events outside of human control*

The awareness that the inclusion of automated technologies was required in the context tables as well as being included as a classification element led to an "event" concept being created at the level of local interactions. The "event" concept can be used to describe any occurring events that are beyond human control, for example, automated technology failure or natural events. The inclusion of this concept would not impact upon the design of the model of collaborative human error because they do not directly involve human intervention.

*Change 2.3: Task analysis can be used to split large studies into manageable segments*

The information gained from the task analysis was integrated into the context tables in two main ways. Firstly, the task analysis was used to segment the analysis into manageable segments. An overall social context table was created for summarising the context that existed for the entire LASCAD study. This proved to be valuable in maintaining an awareness of the impact that certain contextual elements had on the occurrence of the erroneous situation. Secondly, lower levels of the task analysis could be included to complete the "task" concept at the level of local interactions. The tree structure was substituted for a numerical approach of illustrating the task hierarchy.

This allowed agent and tool concepts to be associated with the tasks that were being conducted.

#### 6.4.3.2 Changes to be Implemented for Future Studies

The previous section described changes that were implemented during the application of the classification model to the erroneous situation present in the LASCAD study. This section describes further changes that were implemented for the following studies in this research.

*Change 2.4: Gaining a more complete understanding of collaborative human errors*

This study has highlighted a number of issues that improve our understanding of collaborative human errors and their occurrence. These issues have been addressed through alterations to the classification model as previously described but some require only a stated awareness of their existence. The lessons learned about collaborative human errors in this study include the following:

1) Collaborative human errors are not restricted to a single time period but have impacts and effects over an extended period of time both prior and subsequent to the erroneous event. For example, the LASCAD system failure was partially caused by the failure to appoint an appropriate supplier. The model of collaborative human errors must consider the important issue of error latency;
2) An erroneous situation can rarely be described using a single error classification but requires multiple classifications to understand reasons for its occurrence and the impacts that it has. For example, the failure for the SO references to be followed up (Error 10) was described using three classifications;
3) There are common patterns emerging in relation to the way collaborative human errors evolve through the three levels of context;
4) There are different types of collaborative human error that can be described using different structures of the classification notation; and
5) The top-down approach to applying the classification model proved a useful approach in the case of paper-based case studies. An alternative approach may be

required for more open-ended and unknown case studies such as those described in phase 3.

These points improve our understanding of collaborative human error and are realised in new definitions being created for collaborative human error and adaptations to the model and the way in which it can be applied. The new definitions for collaborative human error and the resulting adaptations to the model are seen in Chapter 4.

This study has enabled the classification model to be developed to a point where it can be effectively applied for the examination of collaborative human errors. The study has also provided a good understanding of what collaborative human errors are and how they occur.

This study increased the validity that the classification model was applicable to real-life examples of collaborative human error. The classification model was seen to describe all the erroneous environments identified in the LASCAD case study. Some situations that were identified highlighted adaptations to the way in which the classification model was applied but the fundamentals of the model held true. In addition to adding validation to the classification model the case study also increased the understanding of how collaborative human errors occur and suggested further changes to the model.

### *Change 2.5: New definitions for collaborative human errors and changes to the model*

A new definition was added to incorporate the time aspect of situations affected by collaborative human error. This definition addresses collaborative human error situations that arise over a certain period of time. This definition can be seen below and is described in Section 4.1 of Chapter 4.

1) **Collaborative human error** – A series of collaboration failures leading to and resulting from an erroneous situation; and
2) **Erroneous situation** – The occurrence of a situation resulting from collaboration or having an impact upon subsequent collaboration that deviates from a norm and is regarded to be undesirable by one or more collaborating agents.

### *Change 2.6: Modified notation to accommodate new error types*

The realisation that the intended notation structure could not describe all errors led to a review of the notation to create new structures that could be used to describe different types of collaborative human error. This review led to the creation of the four different structures seen in Section 6.3.1.3. The requirement for these structures illustrates that the following types of collaborative errors exist:

1) TASK_No.: agent(ERROR_TYPE: contextual element)-agent(ERROR_TYPE: contextual element)
   *Describes an error where there is a conflict between different contextual elements belonging to different agents.*

2) TASK_No.: agent, agent(ERROR_TYPE: contextual element)-(ERROR_TYPE: contextual element)
   *Describes an error where multiple agents have the same context elements but the combinations of contextual elements are inappropriate for both agents.*

3) TASK_No.: agent(ERROR_TYPE: contextual element)-(ERROR_TYPE: contextual element)
   *Describes an error where a single agent is working in an environment where a combination of contextual elements is inappropriate.*

4) TASK_No.: agent(ERROR_TYPE: contextual element)
   *Describes a single user error at the level of local interactions.*

The above structures illustrate that collaborative human errors can occur either due to a failure in collaboration or due to an inappropriate combination of contextual elements. The structure also shows how single user human errors can be described at all levels of the model.

*Change 2.7: Avoid duplication of contextual elements in context tables and avoid ambiguous references*

The LASCAD study identified that there was a risk of duplicating contextual elements arising in the context tables. This occurred because the same contextual elements were referred to differently in two different parts of the study. The size of the study acted to make the identification of these duplicated elements more difficult. This caused ambiguities in the notation and led to confusions in analysis. Grouping the contextual elements according to similar properties that they possess helps to make the identification of duplicated items more clear. However, an awareness needs to be maintained that there is a risk of duplication occurring and that contextual elements need to be distinguished clearly.

*Change 2.8: Recognition of responsibility and use of contextual elements in the model*

In creating the notations a problem existed of deciding which agent a contextual element was associated with. An agent can own, create, experience or use a contextual element but the notation does not distinguish between these relationships. However, these relationships can be indicated, to some degree, at different levels of the model.

At the level of social context an agent creates or owns a structure or a goal or experiences a history. The important aspect at this level is who is responsible for a structure or for a goal. This indicates who is responsible for a certain contextual situation existing at the level of situation context. Simply identifying the user of a contextual element at the level of social context has limited value in that it tells us little about why the contextual element was used in the first place. By identifying who is responsible for the existence of a contextual element the examination of an erroneous situation can be traced back to the process involved in its selection.

At the level of situation context and local interactions it is only useful to identify who uses a contextual element. This is because, at these levels, the only interest is in the impact that the contextual elements have on actions that are performed. The conclusion arising from this is that at the level of social context agents are referred to in terms of the contextual elements that they are responsible for. At the lower two levels agents are referred to in terms of the contextual elements they use or are directly affected by.

*Change 2.9: Clarifying the distinction between plans and interests*

The concern over the inability to effectively distinguish between interests and plans continued into this study. Situations arose where collaborative human error classifications had to include the interest concept even though the interest was not explicitly stated. These situations did, however, give a better indication of how these concepts can be distinguished.

1) **Interest:** An interest can be described as an attention focus of an individual. This attention focus can appear in an error classification through not being appropriate for a situation, through it not being possible due to certain opportunities or through it being lacking; and
2) **Plan:** A plan can be described as a task sequence that has been formed to fulfil a goal based upon the opportunities and interests that exist. To be included within an error classification the plan must have been manifested into a series of actions.

The observations made in this study have helped to clarify the distinction between these two elements and have added validation that they are, in fact, two distinct concepts.

*Change 2.10: Ensuring consistency of contextual elements between groups and individuals*

In creating the human error description for the LASCAD case study the importance of consistency in descriptive data was realised. It became apparent that there was some ambiguity arising between contextual elements associated with groups and associated with individuals within those groups. It is possible for an agent to be associated with contextual elements that are not associated with the group the agent belongs to. The differences should be indicated through the relevant level of abstraction in the context table hierarchy.

## 6.5 Summary

This chapter has summarised the findings from phase 2 of this research. Phase 2 initially tested the fundamental aspects of the classification model in a low-risk setting. The chapter described how phase 2 was split into two main studies consisting of the Kegworth Study and the LASCAD study. The studies were used to develop the classification model through their application to paper-based case studies.

The first section describes the application of the model and classification to the Kegworth Case Study. The Kegworth study provided a relatively small study to test the model and classification and to establish the requirements of a framework for applying them. The changes to the model and classification resulting from this study were described in the second section.

The third section describes the application of the classification model using an application framework to provide a structured application. During this study refinements were made to the classification model and the way in which it was applied based on issues that were identified. Through this study a number of lessons were learnt and a more complete understanding was gained about the occurrence of collaborative human errors. The changes to the classification model resulting from this study were described in the fourth section.

The result of this phase was a new definition of collaborative human error and a classification model that has been developed, refined and tested based on two paper-based case studies. In addition to this a framework has been specified for the application of the classification model. This set of techniques is based on those commonly used for human error analysis and has been adapted for collaborative human errors. Using paper-based case studies offered a low risk platform to test and develop the classification model. The classification model was at a stage in its development where it could be applied to observed examples of collaborative human error. This would further test the classification model and provide the opportunity to learn more about the occurrence of collaborative human error. This application is described in the following chapter.

# Chapter 7

## 7 The Observational Studies

This chapter evaluates the classification model and the application framework by describing its application to examples of collaborative human error. Phase 2 examined the application of the classification model in relation to documented case studies including the Kegworth Accident study and the LASCAD case study. The focus of Phase 3 is to explore the application of the classification model in a corpus of observed collaborative human errors. This addresses the problems associated with documented case studies and examines errors in the natural environments in which they occur.

The documented case studies used in Phase 2 were useful in providing valuable information relating to the causal issues of human errors. However, the evaluation relied upon the data that was presented in the case study reports and thus could be biased towards the conclusions drawn in these reports. In reports such as these the emphasis is on attributing blame and the details can be incomplete and inaccurate (Reason 1990). These studies also focused on high-level collaboration and did not provide detailed explanations of low-level interactions with the systems.

The purpose of Phase 3, as described in this chapter, is to further evaluate the classification model and the application framework by applying these elements to a naturalistic corpus of collaborative human errors. The examination tests the research elements against these observed examples of human error to indicate changes that will improve them and test the applicability of a collaborative approach. The errors observed through naturalistic corpus gathering allow the classification model to be applied to erroneous situations involving interactions occurring within small groups of individuals. Phase 3 of this research examines examples of collaborative human error from two sources as described in the following:

1) ***Errors observed in a collaborative diagram building task.*** The groupware environment was set up to provide a difficult environment for the users to complete their task and thus encourage the occurrence of human error; and
2) ***The WitStaffs case study.*** This study provided a platform that would allow many of the concepts present in the classification model to be examined. This enabled an examination of collaborative human error that was not dependent upon the details within incident or accident reports. This could be used to further validate the concepts present within the classification model and further develop our understanding of collaborative human error.

This chapter is split into four main sections. Section 7.1 describes how the classification model was applied to the collaborative diagram building task. Section 7.2 describes how the classification model was developed from this study. Section 7.3 describes the errors observed in the WitStaffs project. This is followed by Section 7.4 which describes how the classification mode was developed from this study and identifies areas for future research.

## 7.1 Errors Observed in a Collaborative Diagram Building Task

This study looks at Version 2 of the classification model and application framework in relation to an examination of a corpus of low-level examples of collaborative human error observed during a collaborative diagram building task. The errors from this study were described in Chapter 5. The following gives an overview of each of these errors.

1) *Omission of data in instruction.* An agent forgets an item when giving instructions to other agents on how to complete a task; and
2) *Reading an email out of the context in which it was written.* An agent sends an email in response to a request from the instructor. A delay in the transmission results in the email being read in the context of a different task.

The data from these studies was collected through email logs and video footage acquired from camcorders that recorded each of the participants. Each participant was interviewed after each experimental session. The data at the level of local interactions is described in this section as it applies to both errors in this case. The task analysis in Figure 7.1 for the collaborative diagram building task is common to both errors.

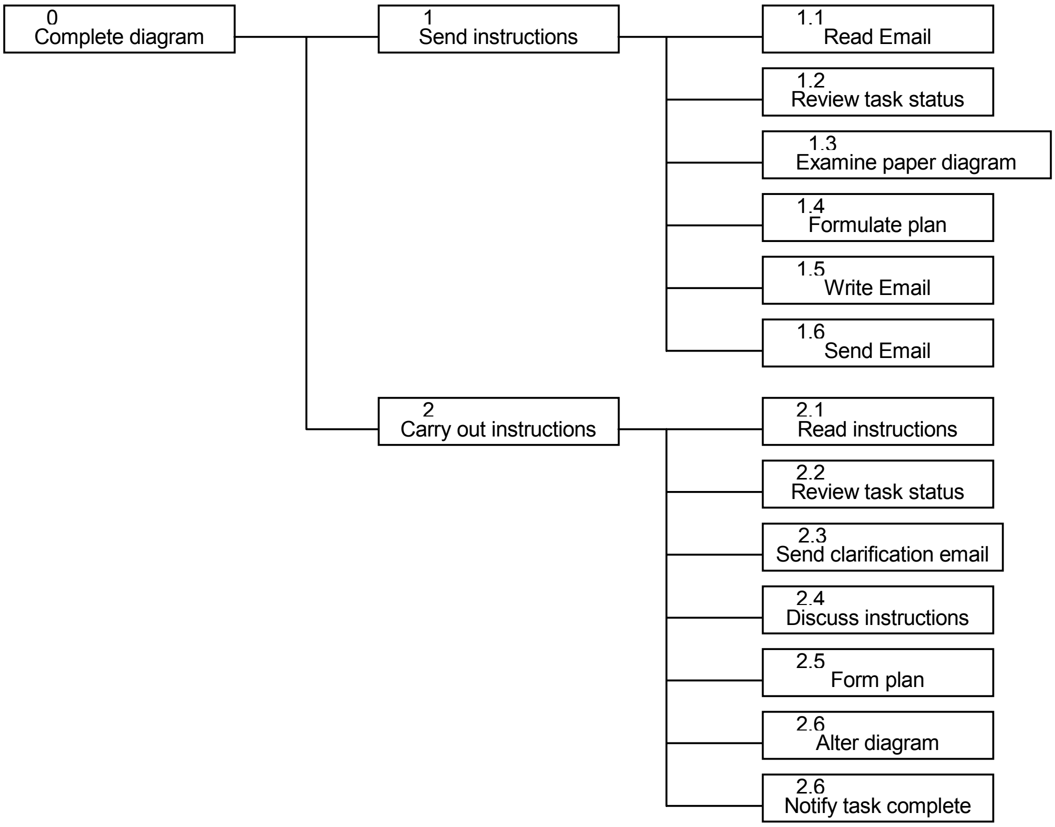


Figure 7.1: Task analysis for the collaborative diagram building task

The task analysis in Figure 7.1 shows a correct sequence of interactions for successfully completing the diagram building task. In both cases this sequence breaks down somewhere to become erroneous. The data in Table 7.1 describes the local interaction context table that applies to both errors.

The task analysis and the context table in this section describe the context of the errors at the level of local interactions that applies to both errors. The contextual descriptions at the level of situation context and social context, the subsequent classification and analysis are described later.

Table 7.1: Local interaction context table for the collaborative diagram building task

| Local interactions involved with the error | | | |
|---|---|---|---|
| **Agent** | **Task** | **Tool** | **Event** |
| Instructor | Read email, review task status, examine paper based diagram, formulate plan, write email, send email | Email, paper diagram | |
| Builder1 | Read email, review task status, send clarification email, discuss instructions, form plan, alter diagram, send task complete notification. | Email, videoconference, [workspace: boxes, lines, labels] | |
| Builder2 | Read email, review task status, send clarification email, discuss instructions, form plan, alter diagram, send task complete notification. | Email, videoconference, [workspace: boxes, lines, labels] | |

The next section describes the omission of data from the instruction example and the second section describes the lack of understanding of email norms example. This is followed by a description of how this examination contributed to the research in terms of identifying problems and proposes suitable changes to the research elements.

### 7.1.1 Omission of Data in Instructions

The following sections describe the organisation of the data, the error classification and the error analysis for the omission of data in instructions error example according to the requirements of the application framework (Appendix D2.1).

#### 7.1.1.1 Organising the Data

The data is organised using a task analysis and a series of context tables. The task analysis for the task under investigation can be seen in Figure 7.1. This task analysis shows the actions required to complete the DFD. This section describes the organisation of the data relating to local interactions, situation and social context that are specific to the omission of data from instruction error example.

The task analysis in Figure 7.2 shows the sequence of actions that led to the incorrect deletion of the D11 data store box from the diagram. These interactions are structured in a local interaction context table as seen in Table 7.2. Only the interactions contributing to the error are organised in this context table because the other interactions have already been organised in Table 7.1.

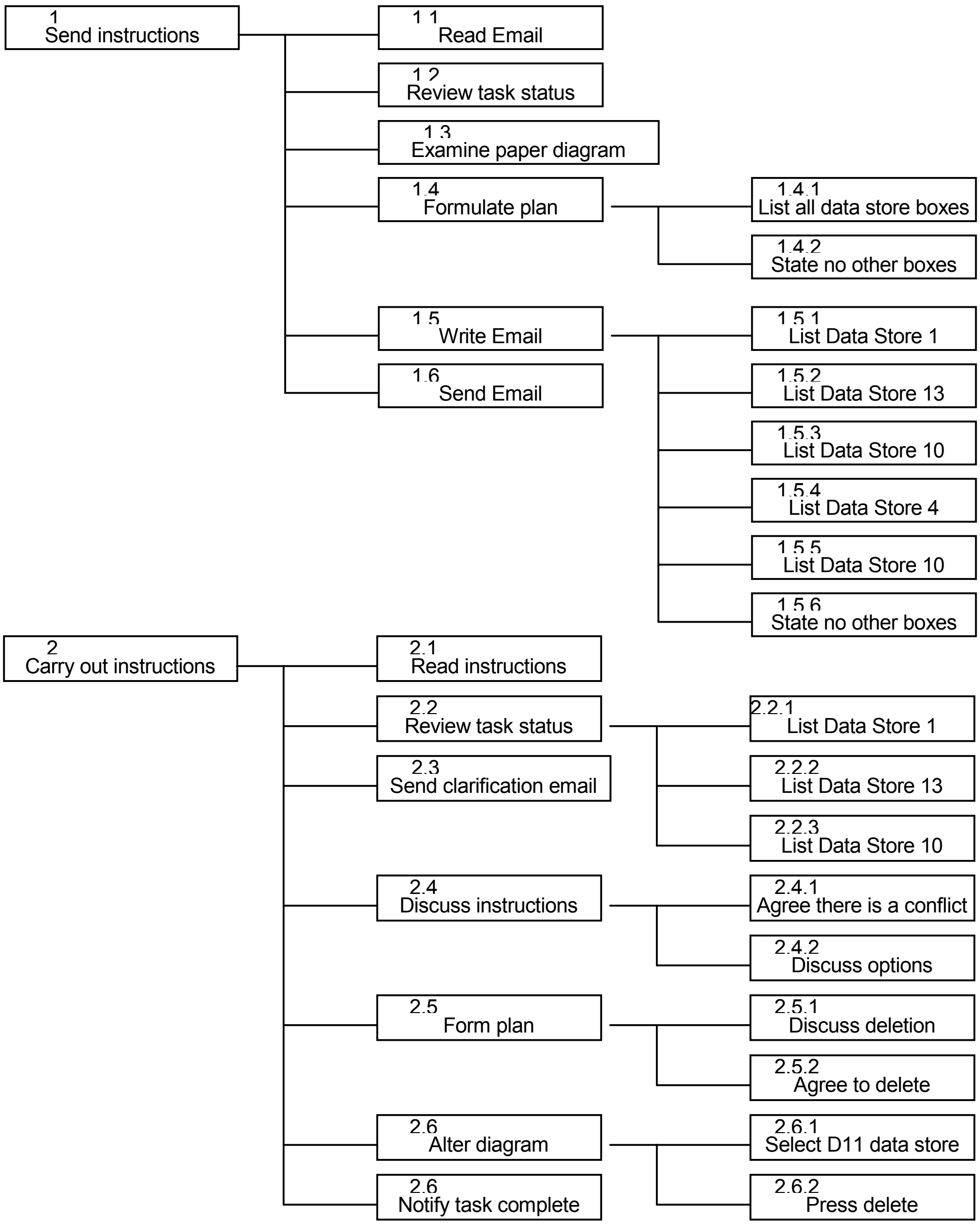


Figure 7.2: Task Analysis for the omission of data in the instruction error example

The context table in Table 7.2 describes the local interaction context for the erroneous situation. In this study there were only three agents which included the instructor and the two diagram builders. The two diagram builders have the same high-level roles but builder 1 performs the task of deleting the D11 data store box. The tasks have been grouped according to the high-level task they apply to. No external events occurred, in this case, that affected the interactions.

Table 7.2: Local interaction context table for the omission of data from instruction error

| Local interactions involved with the error | | | |
|---|---|---|---|
| **Agent** | **Task** | **Tool** | **Event** |
| Instructor | [Formulate plan: List all data store boxes, state that no other data stores are present], [write email: list data store 1, list data store 13, list data store 10, list data store 4, list data store 10, state no other data stores exist] | Email, paper diagram | |
| Builder1 | [Review task status: examine diagram, compare to instructions, realise a D11 data store exists] send clarification email, [discuss instructions: agree conflict exists, discuss options], [form plan: discuss whether to delete, agree to delete], [alter diagram: select D11 data store box, press delete] | Email, videoconference, [workspace: boxes, lines, labels] | |
| Builder2 | [Review task status: examine diagram, compare to instructions, realise a D11 data store exists] [discuss instructions: agree conflict exists, discuss options], [form plan: discuss whether to delete, agree to delete] | Email, videoconference, [workspace: boxes, lines, labels] | |

The study of local interactions has provided an insight into the events that led to the occurrence of the erroneous situation. A study of the situation and social context can give an indication of why they occurred in that specific way. Table 7.3 describes the situation context for this example error.

Table 7.3: Situation context table for the omission of data from instruction error

| Situation context involved with the error | | | |
|---|---|---|---|
| **Agent** | **Opportunities** | **Interest** | **Plans** |
| Instructor | Email, [paper diagram: boxes, lines, labels] | To provide instructions, builders to complete diagram, constructing next set of instructions. | [Group boxes according to type, include boxes in email, delete all other boxes of same type] send instruction in diagram and text form |
| Builder1 | [Email: instructions], videoconference, workspace, [diagram: [boxes: D11 data store box], lines, labels] | Build diagram, delete D11 data store box | Read email, discuss instruction, edit diagram, delete box |
| Builder2 | [Email: instructions], videoconference, workspace, [diagram: [boxes: D11 data store box], lines, labels] | Build diagram, keep D11 data store box, get verification | Read email, discuss instruction, confirm instruction, edit diagram, delete box |

Table 7.3 describes the situation context table for each of the three agents. Differences between the Instructor and the two builders are expected as they have different roles. The two builders are expected to have similar contexts as reflected in the opportunities. The opportunities show that the builders had a D11 data store box on their partially built diagram. There are differences in the interests of all the agents. The context table shows that Builder 1 was interested in deleting the D11 data store box and Builder 2 wanted to keep it. This difference is again reflected in the plans of the two builders. Table 7.4 describes this example from the level of social context.

Table 7.4: Social context table for the omission of data from instruction error

| Social context involved with the error | | | |
|---|---|---|---|
| **Agent** | **Structure** | **Goal** | **History** |
| Instructor | Team dynamics, student | Complete task | |
| Builder1 | Team dynamics, lecturer | Complete task | Taught Builder 2 |
| Builder2 | Team dynamics, student | Complete task | Attended lectures by Builder 1 |

Table 7.4 describes the social context table for each of the three agents. The structures indicate that one of the builders was a lecturer and the other was a student. The overall

goal of all the agents was identical. The history shows that that lecturer had previously taught the student.

This section has described the contexts that were present in this error example. The following section describes the classification and description for this error example.

#### 7.1.1.2 Error Classification and Description

This section describes the error classification and description for the omission of data from instruction error example. The section describes the classifications according to each level of context starting with the level of local interactions, followed by errors at the level of situation context and then errors at the level of social context.

The errors at the level of local interaction can be seen in the following error list:

1) TASK 1.4.1: Instructor(SB-TOOL: paper diagram, data store boxes)
2) TASK 1.5: Instructor(KB-TASK: write email, D11 data store not included in instruction)
3) TASK 2: Builder 1, Builder 2(KB-TOOL: workspace, data store boxes)
4) TASK 2.6: Builder1(RB-TASK: delete D11 data store box)

This error list for local interaction states that the Instructor made a skill-based error in overlooking the D11 data store box when examining the paper diagram and assessing what should be in the instructions (1). In writing the instruction email the Instructor made a knowledge-based error when writing the incomplete email based on the incomplete knowledge gained from the perception of the diagram (2). The builders then made knowledge-based errors of the workspace because they had incomplete information and had to discuss whether the box should or should not be there (3). Builder 1 then makes a rule-based error in the task of deleting the D11 data store box (4). At this point the Instructor believes the correct instructions have been sent. According to the instructions the builders have made a correct decision in deleting the D11 data store box. It is only during later events that these events can be detected as being erroneous.

The errors of situation context can be seen in the following error list:

5) TASK 0: instructor(INT: builders to complete diagram)-builders(OP: email, instructions)
6) TASK 2: builders(OP: email, instructions)-(OP: workspace, diagram, boxes, D11 box exists)
7) TASK 2.6: builder1(INT: delete box)-builder2(INT: keep box)
8) TASK 2: builder1(PL: delete box)-builder2(INT: Get verification)
9) TASK 2: builders(PL: edit diagram)-(OP: email, instructions)
10) TASK 2: builders(INT: build diagram)-(PL: delete box)

In this error listing for situation context it can be seen that the Instructor's interest for the builders to complete the diagram was impeded by the opportunity presented to the builder by the information in the instructions sent by the Instructor (5). There was a conflict of interests within the builder group as a result of this email in that Builder 1 wanted to delete the box and Builder 2 wanted to keep the box (7). Two conflicting plans were formulated in order to fulfil these conflicting interests (8). The builders made an error in the plan to edit the diagram as a result of the information in the email (9) which led to the data store box being incorrectly deleted (10).

The errors of social context can be seen in the following error list:

11) TASK 2: builder1(HIS: Taught Builder 2)-builder2(GL: Complete diagram)
12) TASK 0: builders (STR: Team dynamics)- All(GL: complete diagram)

This error listing for social context states that there were two conflicting goals among the builder agents. The goal to keep the box was not achieved because of the history in the relationship of the builders (11). Builder 1 was a lecturer and Builder 2 was a student and the status of Builder 1 contributed to the decision to delete the D11 data store box (12) thus deviating from the goal to complete the task.

This section has described the error classification and descriptions of the events contributing to the omission of data from instruction example error. The following section describes an analysis of the error.

#### 7.1.1.3 Error Analysis

This example of collaborative human error occurred over a long period of time. The error began with the interactions described above but was not detected until sometime afterwards. The error can be separated into two parts that, firstly, describe the creation of the erroneous instruction email and, secondly, describe the impact that the email has on the two diagram builders.

The incorrect formation of the instructions resulted from an incorrect perception of the paper-based diagram that led to a knowledge-based error in the instruction email. Once the email had been sent the error had consequences to the other agents involved in the task. When this email was sent to the builder group the instructor believed that the email was correct. When the builders received the email they noticed a discrepancy between the instructions and what they could see on the diagram in the workspace.

The decision to delete the box was caused by incorrect information being sent to the builders by the instructor. At the level of situation context the builders received the email and saw that it conflicted with the opportunity presented to them by the diagram on the shared workspace. A box existed on their workspace that did not appear in the instructions. On observing this conflict the builders discussed plans to address this conflict. Based on the information in the email Builder 1 wanted to delete the box. In the context of the instructions this plan was correct and the plan to keep the box was incorrect. However, in relation to the entire task the plan is incorrect and Builder 2's plan to keep the box and seek verification is correct.

At the level of situation context there is an abundance of errors including the interest concept. This indicates that the situation involved personal conflicts between one or more agents. Observations of the actual example show this to be the case. The selection of the plan to delete the box was decided upon because of the instructions at the level of situation context and the status of builder 1 over builder 2 at the level of social context.

In the local interaction context table some differences were seen between the two builders who had exactly the same role. This difference was that builder 1 deleted the D11 data store box. In this context this difference appears to be relatively minor. The situation context gives some insight into why that difference existed and identifies a more significant issue related to the different interests and plans of the two agents. The task analysis in Figure 7.2 shows that the plan of builder 2 to keep the box and verify the instructions was correct but builder 1's plan was executed. The social context table indicates that Builder 1 was of a higher status than Builder 2 and this may have impacted upon Builder 2's action being executed.

This section has described the data organisation, classification and description and analysis of the omission of data in instruction example error. The following section describes a further example occurring in the same study.

### 7.1.2 Email Read out of Context Error Example

The following sections describe the organisation of the data, the error classification and the error analysis for email read out of context example error according to the requirements of the application framework (Appendix D2.2).

#### 7.1.2.1 Organising the Data

The task analysis for the diagram building task can be seen in Figure 7.1 and the tasks are described in the local interaction context table seen in Table 7.1. This section describes the organisation of the data relating to local interactions, situation and social context that are specific to this error example.

The task analysis in Figure 7.3 shows the sequence of actions that led to the confusion resulting from an email being read out of context.

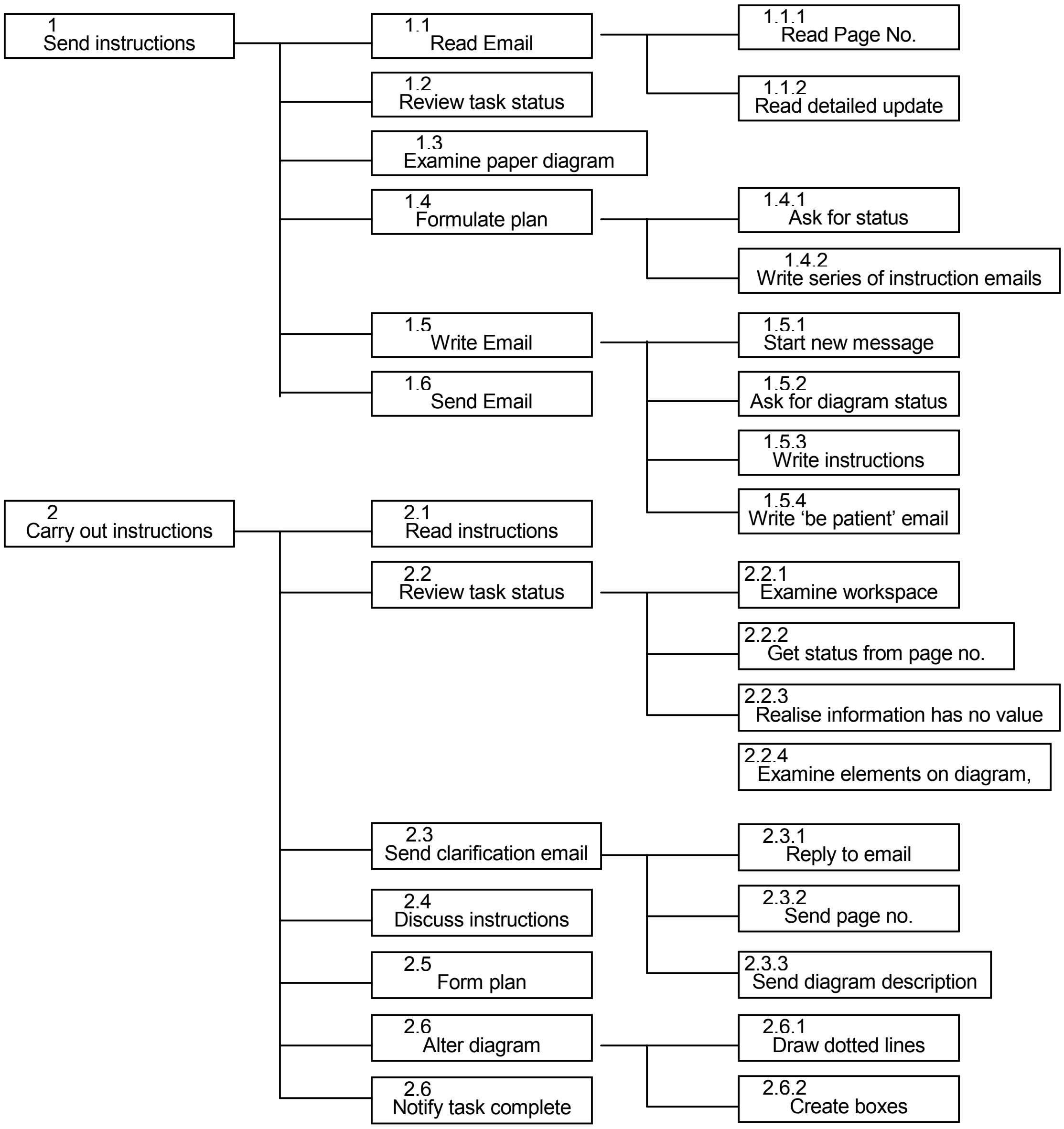


Figure 7.3: Task Analysis for the email read out of context error example

The interactions in the task analysis in Figure 7.3 are structured in a local interaction context table seen in Table 7.5. Only the interactions contributing to the error are organised in this context table because the other interactions are described in Table 7.1.

Table 7.5: Local interaction context table for the email read out of context error example

| Local interactions involved with the error | | | |
|---|---|---|---|
| **Agent** | **Task** | **Tool** | **Event** |
| Instructor | [Read email: Read page number, read detailed update], [Formulate plan: ask for status, write series of instruction emails], [write email: start new message, ask for diagram status, write instructions, write 'Be Patient' email] | [Email: send message, receive message, messages], paper diagram | Email delivery slow |
| Builder 1 | [Read instructions: open email, read new message], [Review task status: look at workspace, get status from 'Page No.', realise Page No. has no value, examine elements on diagram], [Send clarification email: reply to email, send Page No., send detailed diagram status] | [Workspace: drawing tools, diagram, page no], [Email: send message, receive message, messages], videoconference | Email transmit slow |
| Builder 2 | [Read instructions: open email, read new message], [Alter diagram: draw dotted lines, create boxes] | [Workspace: drawing tools, diagram], [Email: receive message, messages], videoconference | |

The context table in Table 7.5 describes the local interaction context for the erroneous situation. In this example error the builders choose to perform different tasks. Builder 1 is participating in all of the communication whereas Builder 2 is reading the instructions and drawing the diagram but not sending any emails. This is reflected in the tools that are used by Builder 2. Builder 2 uses the email tool only as a tool to receive messages.

The event column has two entries: one for Builder 1, and the other for the Instructor. These event entries relate to a slow period in the email transmission affecting the speed of delivery.

The study of local interactions has provided an insight into the events that led to the confusion caused by an email being read out of context. A study of the situation and social context can give an indication of why they occurred in that specific way. Table 7.6 describes the situation context for this example error.

Table 7.6: Situation context table for the email read out of context error example

| Situation context involved with the error | | | |
|---|---|---|---|
| **Agent** | **Opportunities** | **Interest** | **Plans** |
| Instructor | [Email: send message, receive message, messages, no email received from Builder 2], paper diagram, email delivery slow | Get the status of builders diagram, deliver instructions | Ask for diagram status, write a series of email instructions |
| Builder 1 | [Workspace: drawing tools, diagram], [Email: send message, receive message, messages], videoconference | Make sure diagram is complete | Get screen status from 'Page No.' information, Get screen status from diagram |
| Builder 2 | [Workspace: drawing tools, diagram], [Email: send message, receive message, messages], videoconference | Make sure diagram is accurate | Let other two discuss diagram content, read instructions, draw boxes with dotted lines |

The opportunities available to the two builders are identical (Table 7.6). In the local interaction table it was noted that Builder 2 was not contributing to the communication with the instructor. This fact is noted as an opportunity for the instructor. The slow transmission event has also been presented as an opportunity.

The interests of the agents are all different. The interest of the instructor is to first get the status of the builder's diagram. This interest then changes to an interest to deliver instructions to them. The interests of the builders differ in terms of completeness and accuracy. Builder 1 wants to get all of the elements onto the diagram. Builder 2 wants the elements to look identical to the Instructor's version of the diagram.

The interests of all the agents are reflected in the plans that they form to get the task completed. The Instructor forms a plan to get the status of the builder's version of the diagram. The Instructor then creates a new plan to write a series of emails, each one describing a certain group of elements that exist on the paper version of the diagram. Based on an email received as a result of the initial plan of the investigator Builder 1 plans to get the screen status from the diagram page number and sends an email to that effect. On realising that this information is of no value the builder forms a plan to examine the diagram on the screen and sends a detailed description to the investigator. Builder 2 forms a plan to let Builder 1 and the investigator get on with the communication while he follows the instructions. His interest in accuracy leads him to draw dotted boxes as there is no dotted box tool in the workspace toolbox.

The situation context table describes how the agents are working together. These elements are made clearer in the social context table for this example in Table 7.7.

Table 7.7: Social context table for the email read out of context error example

| Social context involved with the error | | | |
|---|---|---|---|
| **Agent** | **Structure** | **Goal** | **History** |
| Instructor | Team dynamics, [Role: Instructor], student | Complete task | No knowledge of role agreement |
| Builder1 | Team dynamics, [Role: Communicator and diagram builder], student | Complete task | Roles agreed via videoconference |
| Builder2 | Team dynamics, [Role: Diagram builder] student | Complete task | Roles agreed via videoconference |

The context table (Table 7.7) shows that each of the two builder agents in the task adopted different roles. Builder 1 took on the roles of communicator and builder while Builder 2 only took on the role of builder. These roles were mutually agreed during the start of the session through the videoconference but were not communicated to the Instructor. All agents have the common goal of completing the task.

This section has described the context of this error example. The following section describes the classification and description of the events in this error example.

#### 7.1.2.2 Error Classification and Description

This section describes the error classification and description for the email read out of context error example. The section describes the classifications according to each level of context starting with the level of local interactions, followed by errors at the level of situation context and then errors at the level of social context.

The errors at the level of local interaction can be seen in the following error list:

1) TASK 2.2.2: Builder 1(RB-TOOL: Workspace, page no.)
2) TASK 2.3.2: Builder 1(RB-TASK: Send clarification email, send Page No.)
3) TASK 2.3: Email(TF-TOOL: Email delivery slow)
4) TASK 1.1.1: Instructor(KB-TOOL: Email, messages)

At the level of local interactions it can be seen that Builder 1 makes a rule-based error in selecting to examine the page number status of the diagram in response to the Instructor's request for an update on what the Builders have on their screen (1). Builder 1 then makes a subsequent rule-based error in selecting to send the message to the instructor (2). There was then a technical failure in the transmission of email causing the slow delivery of a detailed email providing a second answer to the Instructor's initial request (3). This technical failure caused the email to be received while the instructor was involved in another task. The Instructor did not know the context in which this email was sent (4).

The errors of situation context can be seen in the following error list:

5) Task 0: TASK Instructor(PL: Ask for diagram status)- Builder1(PL: Get screen status from 'Page No.')
6) TASK 1: Instructor(PL: Ask for diagram status)-(OP: Email: no email received from Builder 2)
7) TASK 0: Instructor(PL: Ask for diagram status)-Builder 2 (PL: Let other two discuss diagram content)
8) TASK 0: Builder1(PL: Get screen status from diagram)-Instructor(INT: deliver instructions)
9) TASK 0: Builder1(PL: Get screen status from diagram)-Instructor(PL: write a series of email instructions)
10) TASK 2: Builder 1(INT: Make sure diagram is complete)-Builder2(INT: Make sure diagram is accurate)

At the level of situation context the Instructor asked for the status of the Builder's diagram but this was not fulfilled by Builder 1's plan to get the status of the diagram from the 'Page No.' (5). The plan was further disrupted by the fact that the Instructor got no emails from Builder 2 (6). This was because Builder 2's plan was to let Builder 1 communicate with the Instructor while he altered the diagram (7). When the Instructor does get a useful email from Builder 1 the instructor's interests have changed (8) and he has already moved onto his second plan to write a series of email instructions (9). The Instructor believed this email was related to the instruction emails he was sending but had misunderstood the purpose of the mail (4). The final error is a conflict of interests between the two builders (10). This is not directly related to the example error but may indicate a further reason for Builder 2's lack of communication with the investigator.

The errors at the level of social context can be seen in the following error list:

11) TASK 0: Instructor (HIS: No knowledge of role agreement - Builder1, Builder 2 (HIS: Roles agreed via videoconference)
12) TASK 0: All (STR: team dynamics)-(GL: Complete task)

At the level of social context there are two possible conflicts that impact upon the error example. The first error relates to the agreement of roles made by the two builders. This agreement was not communicated to the Instructor (10). The second error relates to inappropriate team dynamics that impact upon the common goal to complete the task.

This section has described the error classification and descriptions of the events contributing to the email read out of context example error. The following section describes an analysis of the error.

#### 7.1.2.3 Error Analysis

This case is an example of collaborative human error involving both human error and technology failure. At the level of local interaction the error was simply a rule-based failure involving the Builder inferring an inappropriate element of the screen to report status on. A second rule-based error was made in sending this email to the Instructor. Builder 1 discovered his error and attempted to recover from it by sending a detailed email describing the status of the diagram. The technical failure prevented the Investigator receiving this email before initiating his new plan. When the Investigator read the email it was read in the context of the new plan and not in the context that it was sent. This confused the Instructor and led him to send an email asking Builder 1 not to 'be so impatient'.

The cause of this error at the level of situation context consisted mainly of planning conflicts. A large number of planning conflicts occur because the agent's plans are changing but not being communicated due to either technical or other reasons. The investigator changes his plan because he is not getting the right feedback or any feedback at all. His second plan generates a new interest to send instructions which means his attention is now on instructions as opposed to receiving status updates. Builder 1 changes his plan because he discovers an error in his original plan. Builder 2 does not change his plan but his plan conflicts with the investigators.

A further cause in this example error can be seen in the decision by the builders to allocate roles between themselves but not inform the Instructor. The roles were allocated to prevent the Instructor from getting duplications of data from the two builders. The builders would first discuss the instructions then send feedback through Builder 1. This would be fine though the overall team dynamics were not effective in achieving the overall goal.

This study shows how the classification model and application framework were applied and developed through small examples of collaborative human error. The changes were implemented into the classification model to be applied to the following examples of collaborative human error that were observed during the implementation and use of the WitStaffs project groupware environment. The WitStaffs project offered a broader observation study by which a more complete understanding of collaborative human error could be achieved.

## 7.2 Developing Version 3 of the Classification Model

This section describes how the examination of the example errors in the previous sections has contributed to this research. The section first describes the overall contribution to research then describes the issues and problems that were identified through the study. The section then describes the alterations that were made to form Version 3 of the classification model.

### 7.2.1 Addressing the Research Objectives

The previous sections described how the classification model was applied to each example error from the diagram building task. From this examination a number of issues were identified with the classification model and the method by which it was applied. This section describes the contribution to the research by reviewing the objectives of the study specified in Chapter 5.

1) To addresses the problems of paper-based case studies identified by Reason by applying the classification model to observed examples of human error;
2) To contribute to a corpus of low-level errors that could be examined using the classification model;
3) To examine the application of the classification model and the changes made to it as a result of Phase 2; and
4) To identify changes to the classification model and application framework
5) To suggest areas for future work in collaborative human error.

The observation of the errors in these studies was conducted to address the problems that could be experienced in paper-based case studies such as those seen previously in this research. The fact that the example errors were observed first hand in an environment set up by the author meant that the collaborative environment and errors occurring within it were familiar. The familiarity of the studies and the first hand observations meant that new types of data were available that could be applied to the examination of the human error examples. For example, the increased familiarity meant that a correct sequence of actions for each task could be determined and modelled in a task analysis. This task analysis was then used to identify errors and enable a better understanding of their occurrence by determining where in the task sequence they occurred and the agents and objects that were involved. The nature of the studies meant that they focused on the collaborations made by an ad hoc group rather than on the decisions and actions performed by workgroups within organisations.

The studies described in this section contribute a more diverse set of error types to the corpus of errors. The errors examined in the previous sections looked at errors observed during an experimentally controlled groupware session. These studies illustrate previously unseen error classifications such as the Interest-Interest classification. The focus on individuals increased the likelihood of these error types being observed.

The LASCAD study described in Chapter 6 resulted in a number of changes to be implemented in Phase 3 studies. The changes were implemented in the examination of these example errors. The changes are discussed in the following:

1) Elements within the context tables were grouped according to type or according to an element they were contained within (Change 2.1). The elements that required grouping were tasks, objects and opportunities. This helped to structure the data and improved the ability to form the error descriptions and to avoid duplications of classifications.
2) The event concept was seen in the second error where there was a technical failure in the slow transmission of an email (Change 2.2). The additional "Technical Failure" classification type appeared to be appropriate for describing these types of failures.
3) The task analysis played a much more integral role in structuring local interaction data though the studies under examination were not large enough to require the level of segmentation that was required in the studies described in Chapter 6 (Change 2.3).
4) The clearer understanding gained of collaborative human error enabled the studies to be scoped and described at an appropriate level. The previous studies examined the cases from a top-down approach starting at the level of social context. The example errors in this study were examined from a bottom-up approach starting at the level of local interactions. This was possible as a detailed knowledge of the local interactions was possible (Change 2.4).
5) The new definitions enabled a clearer understanding of the elements under examination. An erroneous situation was the situation under examination and a collaborative human error is the sequence of actions causing it and resulting from it (Change 2.5).

6) The modified notation to accommodate different forms of collaborative human error was seen to illustrate the different error types in these studies (Change 2.6). The studies illustrated errors involving errors between individuals through a lack of collaboration, errors arising through correct collaboration and errors involving a single individual.
7) The grouping of contextual elements of the same type within the context tables and the task analysis helped to prevent ambiguities between similar contextual elements and the duplication of the same contextual elements (Change 2.7).
8) The size of the example errors meant that the question of who was responsible for a contextual element at the level of social context was not relevant. This meant that the changes in Change 2.8 could not be tested. This change is examined in the following study.
9) Plan and Interest concepts were seen to be distinct in the example studies (Change 2.9). The reduced size of the studies and the focus on individuals made it easier to distinguish between these contextual elements.
10) The errors examined in this section involved teams of individuals and not workgroups working within organisations. This meant that the problem of contextual elements applying to groups differing from those belonging to their constituent members were not applicable. This meant that Change 2.10 could not be tested. This change is examined in the following study.

Through this study further issues and problems were identified about the classification model and how it could be applied. These issues were addressed during this study and solutions were proposed. Table 7.8 summarises the problems identified through this study and the changes that were implemented to address them.

Table 7.8: Problems and solutions resulting from the example errors

| Change No. | Problems | Solutions |
|---|---|---|
| 3.1 | Adapting the model, classification and application framework for smaller examples of collaborative human error. | A bottom-up approach to applying the classification model was applied. The nature of the example errors meant that there was a focus on individuals as opposed to groups and organisations. |
| 3.2 | Dealing with a greater amount of information regarding local interactions and the erroneous situation. | Comparing a task analysis of the erroneous situation to a task analysis of a correct sequence of actions to gain a more complete understanding of the task sequence involved in the erroneous situation. |
| 3.3 | Contextual elements at the level of social context are related to the individual as opposed to the organisation. | The type of errors examined in this phase meant that the data modelled in the context tables related to individuals as opposed to groups and organisations. No change was necessary to accommodate this information. |
| 3.4 | Observed factors that improve the understanding of the occurrence of collaborative human error. | Issues of error latency need to be factored into the classification model. The combinations of classification types that make up the error descriptions needed to be examined further to identify patterns that may exist. Previously unseen error classifications have been observed. When examining the local interactions all differences that have the slightest impact on the erroneous situation should be examined further to identify any potentially significant issues. |
| 3.5 | Translating contextual elements into the error descriptions. | The hierarchical structure of the contextual elements within the context tables can be incorporated into the error notation. |

Table 7.8 describes the main problems with the classification model and how these problems were addressed through implementing changes. Each of these problems and the subsequent changes are described in more detail in the following sections.

### 7.2.2 Problems Identified Through the Study

The previous section described the contribution to research provided by the examination of the example errors. This section gives a more detailed description of the problems and issues experienced when using the classification model to provide an understanding of collaborative human error in relation to the example errors. The following section describes the changes and considerations that resulted from this study. The problems and issues experienced from this study are listed in Table 7.9.

Table 7.9: Table identifying the problems of the classification model identified from the collaborative diagram building study

| Problem No. | Description |
|---|---|
| 3.1 | Adapting the model, classification and application framework for smaller examples of collaborative human error. |
| 3.2 | Inability to compare collaborative human errors to a correct task sequence. |
| 3.3 | Contextual elements at the level of social context are related to the individual as opposed to the organisation. |
| 3.4 | Observed factors that improve the understanding of the occurrence of collaborative human error. |
| 3.5 | Translating contextual elements into the error descriptions. |

Table 7.9 gives a brief description of the problems of the model identified from the example errors. Each of these problems is described in the points below.

***Problem 3.1:*** The fact that the example errors were much smaller in their scale and focused on the interactions of teams of individuals rather than workgroups meant that a number of adaptations were required to the classification model and application framework. The main adaptations are described below:

- The previous studies described in Chapter 6 adopted a top-down approach to the application framework. This top-down approach examined elements of social context first then situation context and finally local interactions. This approach was not suitable for these example errors in Phase 3 because an understanding of the interactions was required before relevant elements of social context could be identified. In the previous studies a top-down approach was more suitable because the scope was much broader and the studies were attempting to identify a series of erroneous situations that contributed to the main failure. It was not suitable in these examples because there were specific erroneous situations being examined with a confined scope of context.
- The reduced size of the example errors meant that there was a changing emphasis on certain contextual elements because the examination focused on individuals and not on organisations and groups. The previous studies examined groups of people and organisations which means that many of the contextual elements were collective. For example, a plan was a collective plan agreed by all of the individuals

within that group. These studies examined the individuals within the groups and how the contextual elements of the individuals can differ from those of the groups.

- The observed nature of the studies meant that much more information was known about the specific tasks and contextual elements associated with individual actions. This was not possible from the previous studies as this information was not available from the accident and incident reports. This means that data that had not previously been included within the application framework was required to be considered and different types of error were classified.

These issues provide an overview of the impact that these smaller examples of collaborative human error had on the classification model and application framework.

***Problem 3.2:*** The size and familiarity of the studies meant that much more information could be obtained about the individual interactions that occurred during the erroneous situation. This meant that it was much simpler to infer a correct sequence of actions against which the erroneous sequence of actions could be compared. The previous studies described in Chapter 6 did not contain the level of detail required to infer this information. This meant that erroneous situations were not previously compared to correct task sequences. The increased amount of information that was known about the low-level interactions and their associated context meant that opportunities existed to exploit this information to improve the understanding of the task sequences involved in the collaborative human error.

***Problem 3.3:*** Contextual elements at the level of social context are related to the individual as opposed to the organisation. As indicated in the first point the focus of contextual elements was on those applicable to individuals rather than groups and individuals. In the previous studies goal, structure and history were more focused around organisations and groups. The impact of this was that the type of elements fulfilling each contextual element and the means by which they were identified was different. The following describes the impacts on the contextual elements existing at each contextual level starting at the level of local interactions.

Before the examination of these example errors it was expected that there would be a major impact on the elements at the level of local interaction. Much more information was known about the task elements meaning they could be described at a detailed level. The increased knowledge of the tasks meant that a correct task sequence could be inferred against which the erroneous task sequence could be compared. The tool element could also be described in much more detail. For example, each element within the diagram being drawn within the task could be identified individually. The correct task sequence was a new information element not included in previous studies.

The more detailed contextual information at the level of local interactions is reflected at higher levels of the model. There is much more information available enabling a detailed description of the opportunities. This can be inferred from the tools and the events that appear at the level of local interactions. Interests were identified from the detailed knowledge of the communication that occurred between the participants. For example, in the first study it was clear that Builder 1 was interested in deleting the D11 data store box and Builder 2 wanted to keep the D11 data store box. Plans could be inferred from the task sequences that occurred.

The elements existing at the level of social context are far more intangible than those seen in previous studies. In the previous studies structure information could be obtained from formal documentation such as rule and policy documents, goals can be inferred from the actions and direction of an organisation or group and history can be obtained from historical documentation. In these studies goals represent the individual's internal intentions, structures represent the dynamics of the team and history represents previous interactions between the individuals. These previous interactions may have occurred years, months, days or even minutes prior to the erroneous situation.

***Problem 3.4:*** The new examples of human errors meant that new factors were observed that could improve the understanding of the occurrence of collaborative human error. These factors are described in the following points:

- In the Phase 2 studies the issue of error latency was seen to occur over relatively long periods of time. In the first error example in this phase error latency was seen to occur within a period of minutes where an action performed by the instructor that is believed to be correct has an adverse effect on subsequent actions performed by the two builders. Latency needs to be considered further and included within the classification model.
- In the second error example it was apparent that there was a particular dominance of the planning classification type at the level of situation context. In the first error example there was a much more even spread of error classifications and no one type appeared more significant than any other. This might indicate that the second erroneous situation was mainly caused by inappropriate and conflicting plans as opposed to any deficiencies in the opportunities available. The type of error classifications can possibly indicate patterns in the occurrence of erroneous situations.
- In Phase 2 there were some error classifications that had not been seen. These include Structure-Structure errors, History-History errors, Plan-Plan errors and Interest-Interest errors. These example errors have illustrated that all classification types have been seen at least once with the exception of the Structure-Structure error type.
- The example errors have illustrated that apparently insignificant contextual differences at the level of local interaction can indicate significant differences at the higher levels of the model. For example, in the first example error the only difference between the two builders at the level of local interactions was that Builder 1 deleted the D11 data store box. This difference is also expected because both Builders cannot delete the same box. However, the fact that this is an erroneous situation means that this difference required further examination. When the context of the two builders is examined at higher levels it becomes apparent that

there was a conflict between the two builders in the decision to delete the box. The examination also indicates that the incorrect action may have been decided upon due to the difference in status between the two builders.

The above factors describe how these studies have helped to improve our understanding of collaborative human error. These factors are considered within developments of the classification model and application framework.

***Problem 3.5:*** A problem that has existed throughout the studies is how to form the error descriptions in a structured way while maintaining an element of meaning when describing the impact of the contextual elements. Previously the structure has been compromised by including sentences to describe what it is about the contextual element that contributes to the erroneous situation. This means that the descriptions can easily be read but limits the ability of the descriptions to be used for analysis.

This section has described the problems that were experienced during this study. The following sections describe the required changes to the classification model.

### 7.2.3 Changes to the Classification Model

The previous section described issues that were experienced when applying the classification model to the example errors occurring in the collaborative diagram building task. These problems impacted on the ability to generate a more complete understanding of collaborative human error. As a result of identifying these issues alterations were made to the classification model and how it could be applied to the examination of erroneous environments. This section describes the alterations to the classification model resulting from this case study as listed in Table 7.10.

Table 7.10: Table showing changes resulting from Phase 3

| Change No. | Description |
|---|---|
| 3.1 | A bottom-up approach to applying the classification model was applied. The nature of the example errors meant that there was a focus on individuals as opposed to groups and organisations. |
| 3.2 | Comparing a task analysis of the erroneous situation to a task analysis of a correct sequence of actions to gain a more complete understanding of the task sequence involved in the erroneous situation. |
| 3.3 | The type of errors examined in this phase meant that the data modelled in the context tables related to individuals as opposed to groups and organisations. Techniques need to be used for obtaining data relating to individuals, goals, history and structure. |
| 3.4 | Issues of error latency need to be factored into the classification model. The combinations of classification types that make up the error descriptions need to be examined further to identify any patterns that may exist. Previously unseen error classifications have been observed. When examining the local interactions all differences that have the slightest impact on the erroneous situation should be examined further to identify any potentially significant issues. |
| 3.5 | The hierarchical structure of the contextual elements within the context tables can be transferred into the error notation. |

Each of the alterations in Table 7.10 is discussed in relation to how it addresses each of the problems listed previously.

*Change 3.1: A Bottom-Up approach to applying the classification model*

The fact that the observations of the example errors yielded much more information about the local interactions compared to accident or incident reports meant that a number of adaptations had to be made to the way the classification model was applied. These changes are described in the following points:

- A bottom-up application was more appropriate for these studies because a specific and confined erroneous situation was being examined. In the previous studies the scope was much broader and the studies were attempting to identify a series of erroneous situations that contributed to the main failure. A bottom-up application of the application framework was possible and appropriate because the local interactions were known and the scope of the erroneous situation was constrained. A more open-ended study such as those seen in Chapter 6 may suit a top-down approach to first identify the scope before focusing on the detail of local interactions.

- Smaller occurrences of collaborative human error mean that the focus of the examination is on the collaboration between individual as opposed to groups of individuals and organisations. This simplifies the evaluation but requires more detailed studies at the level of local interactions. In the cases that were studied there was no need to extend the examination to include groups and organisations. This was because of the experimental nature of the tasks. Other cases may need to consider a broader scope of examination.
- The increased amount of information that can be captured can be included in the context tables and in the task analysis models. A more structured organisation of elements within the context tables by grouping them according to similarity or the elements they contain can assist in dealing with the additional data.

These points give an overview of the changes that were implemented for the application of the classification model. These changes are elaborated upon further within the remaining points.

*Change 3.2: Using task analysis for comparing correct and incorrect task sequences*

The increased amount of data relating to the local interactions and the erroneous situation meant that it was possible to gain a much better understanding of the collaborative human error. This understanding was achieved by comparing an inferred correct sequence of actions against the erroneous sequence of actions observed in the erroneous situation. This correct sequence could be used to gain a better understanding of where the error occurred, the tasks performed before, during and after and the objects and the agents involved. This understanding could then be transferred into the details entered into the local interaction context table.

*Change 3.3: Using the Social context table to describe the social context of individuals*

The type of errors examined in this phase meant that the data modelled in the context tables related more to individuals than seen in previous studies. This means that different types of data had to be collected relating to the goals, structures and histories of individuals. This data was not always easy to obtain as the social context is concealed within internal cognitive processes and group relationships. No change was necessary to accommodate this information but techniques need to be incorporated to better derive this kind of information. Much of this information had to be obtained from conducting interviews and focus groups with the participants and observing of their behaviour.

*Change 3.4: Improving the understanding of collaborative human errors*

A number of lessons were learnt during these studies that improved the understanding of collaborative human error as described in the previous section. The following points describe how this learning contributed to the classification model.

- The latency of error causes in collaborative human errors can span minutes, days, months or years. In the previous studies error causes of the erroneous situations were seen to arise months before the actual occurrence of the situation. These factors could be included within the History element at the level of social context and then examined further in a separate analysis. In smaller examples it is more difficult to identify when an action is a plan or a task or is a historical event. This was seen in the second example error in this chapter. In this example the latent factor was an agreement of working style that was agreed between the builders but not communicated to the instructor. This was classed a historical event because it had an indirect impact on the erroneous situation. The issue of error latency needs further examination.
- In the second error example it was apparent that there was a particular dominance of the planning classification type at the level of situation context. The first error showed an abundance of Interest-Interest errors which could indicate an erroneous situation involving much personal conflict. The combinations of classification types that make up the error descriptions need to be examined further to identify any patterns that may exist. This could yield a valuable insight into the main contributions of their occurrence.

- The examples have shown at least one occurrence of all error types with the exception of Structure-Structure errors. This allows a more complete understanding of each error occurrence and how they can be distinguished from each other.
- The example errors illustrated that apparently insignificant differences at the level of local interactions can highlight more significant issues at higher contextual levels. When examining the local interactions all differences that have the slightest impact on the erroneous situation should be examined further to identify any potentially significant issues.

*Change 3.5: Using the hierarchical structure of the context tables within the error notation*

The improved structure of the contextual elements within the context table included as a result of Phase 2 enabled the elements to be included in a more structured way within the error description. The hierarchical structure of the contextual elements within the context tables can be transferred into the error notation. This provides a more structured notation and maintains the meaning of the descriptions of the collaborative human error and its context.

## 7.3 The WitStaffs Case Study

This study looks at the classification model in relation to an examination of a corpus of examples of collaborative human error observed during the installation and use of the WitStaffs groupware environment. This study and the errors observed within it were described in Chapter 5. The following gives an overview of each of these example errors.

1) *Setting up the environment and installing the groupware applications.* There were a series of errors involving the installation of the groupware software at the University of the Witswatersrand.
2) *Conflict over tools in a shared workspace.* Two agents wanting to use two different tools but in the same location in the workspace.

3) *Agents joining an incorrect workspace.* Two groups of students in two virtual rooms both performing the same task but in the first room there is little communication resulting in agents joining the second room.

The data from the WitStaffs study was collected through a combination of observation, participation, focus groups and interviews. The participants were interviewed or took part in a focus group after each groupware session. Data at the level of local interactions is described in this section as it applies to all errors in this case. The task analysis for a correct sequence of actions for the WitStaffs study can be seen in Figure 7.4. This task analysis is common to all three errors described in this section.

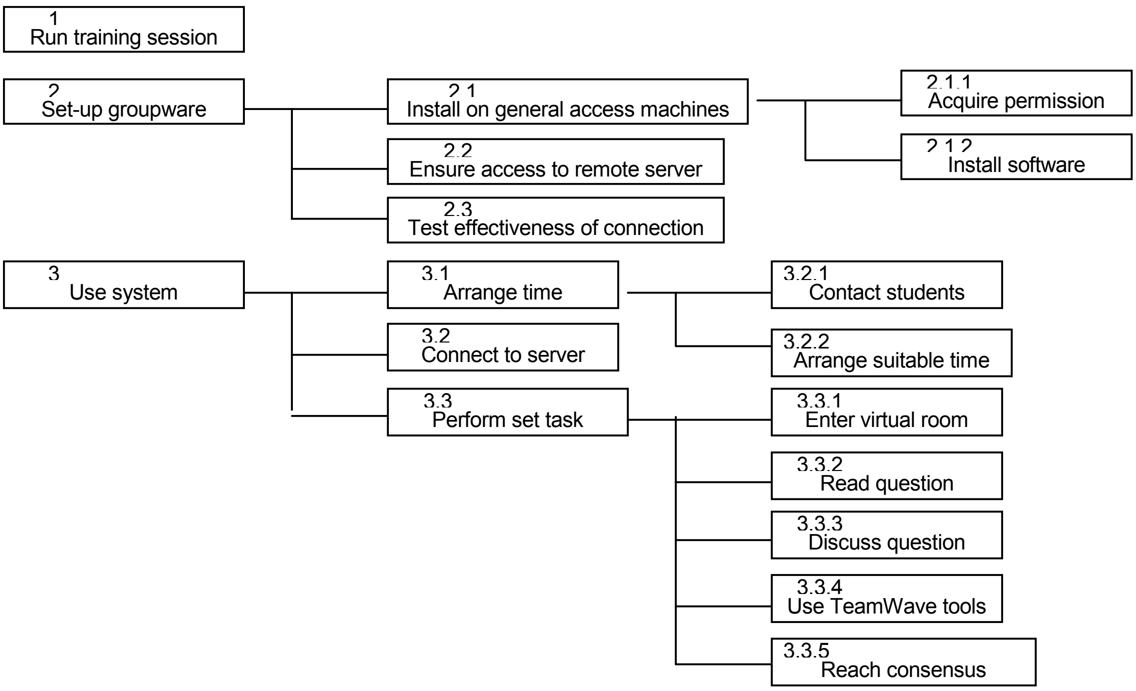


Figure 7.4: Task analysis for the WitStaffs study

In all error examples this sequence (Figure 7.4) breaks down somewhere to become erroneous. The data in Table 7.11 describes the local interaction context table that applies to the errors observed in this study.

Table 7.11: Local interaction context table for the WitStaffs study

| TASK 3:Local interactions involved with system usage | | | |
|---|---|---|---|
| **Agents** | **Tasks** | **Tools** | **Events** |
| Researchers | [Task 1: Run training session, Task 1.1: Get access to training room, Task 1.2: install software, Task 1.3: Arrange training session, Task 1.4: Conduct training session], [Task 2: Set up groupware environment, Task 2.1 Install on general access machines, Task 2.2: Ensure access to remote server, Task 2.3: Test connection], [TASK 3: use system: TASK 3.1: arrange time, TASK 3.2: attend session, TASK 3.3: connect to server, TASK 3.5: monitor use] | [TeamWave client: text chat, voting tool, logging devise], TeamWave server, network, email, computer | connection failures |
| Students | [Task 1: Run training session, Task 1.1: Get access to training room, Task 1.3: Arrange training session, Task 1.4: Conduct training session], [TASK 3: use system: TASK 3.1: arrange time, TASK 3.2: attend session, TASK 3.3: connect to server, TASK 3.4: perform set task] | [TeamWave client: text chat, voting tool], TeamWave server, network, email | connection failures |
| Technicians | [Task 2: Set up groupware environment, Task 2.1 Install on general access machines] | University procedures, computers | |

The task analysis and the context table in this section describe the context of the errors at the level of local interactions that apply to the errors observed in the WitStaffs project. The contextual descriptions at the level of situation context and social context, the subsequent classification and analysis are described in the following sections. The first section describes the problems involved with the installation of the technology; the second section describes the conflict over the same tools in the shared workspace; and the third section describes the events leading to participants joining incorrect workspaces. This is followed by a description of how this examination contributed to the research in terms of identifying problems and proposes suitable changes to the research elements.

### 7.3.1 Setting up the Groupware Environment

The following sections describe the organisation of the data, the error classification and the error analysis for the groupware implementation failure according to the requirements of the application framework.

#### 7.3.1.1 Data Collection

The data for this study was collected through participation in the implementation process and observations of the behaviour of the people involved (Appendix C2). The participation and observations allowed much data to be gathered that fulfilled the requirements of the model of collaborative human error. Some of the data acquired for this study was based on first-hand experience of the author of this thesis. The fact that this may bias the examination has been recognised and the study has been reviewed by other researchers in the study to gain verification of accuracy. The fact that the examination focuses on the application of the classification model rather than the rigorous analysis of the error means that any bias that may appear is of little consequence.

#### 7.3.1.2 Organising the Data

The task analysis for the entire WitStaffs study can be seen in Figure 7.4 and the tasks are reflected in the local interaction context table seen in Table 7.11. This section describes the organisation of the data according to local interactions, situation and social context that is specific to this error example (Appendix C3.1).

During the implementation of the TeamWave software on the University computers there were a series of collaborative errors that led to alternative implementation plans being required. The task analysis in Figure 7.5 shows the sequence of actions that led to the erroneous implementations of the WitStaffs groupware environment.

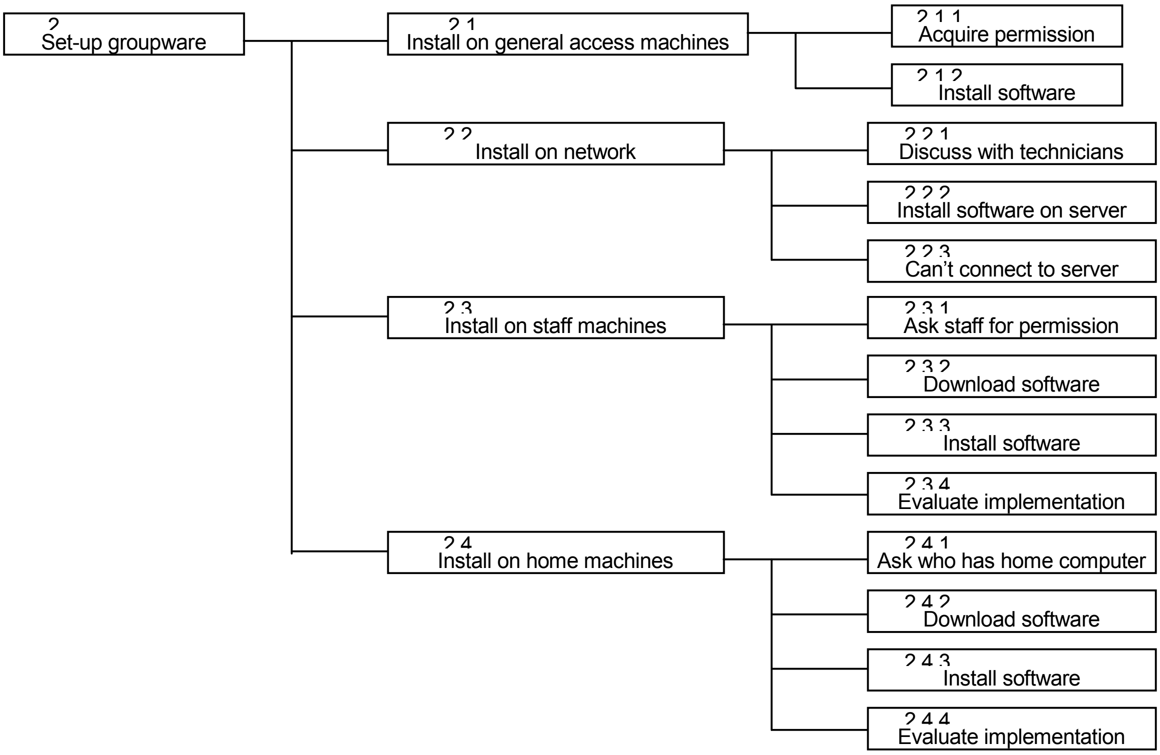


Figure 7.5: Task analysis for the implementation of the TeamWave environment

Task 2.1 in Figure 7.5 describes the preferred plan and Task 2.2 describes a contingency plan that was also not achievable. Task 2.3 and Task 2.4 describe the compromised solution that was adopted for the implementation.

The context table in Table 7.12 describes the local interactions in the implementation of the groupware environment as described in the task analysis in Figure 7.5.

The agents (Table 7.12) are grouped according to whether they are researchers, students or technicians. The more detailed description of local interactions in Table 7.12 separates these groups into the individuals and sub-groups that belong to them. The technicians are referred to as a single group because at this stage they appear to have an indirect impact on the erroneous situation. The student group has been split into sub-groups based on their location. Only the South African student group are involved in this error example. A new agent group has been added to this study that describes the contribution of the 'Staff' group who were not involved in the original plans but played a role in the back-up plan.

Table 7.12: Local interaction context for the TeamWave implementation failure

| Local interactions involved with the error | | | |
|---|---|---|---|
| **Agents** | **Tasks** | **Tools** | **Events** |
| Researchers | [TASK 2: Set-up groupware environment: TASK 2.1: install on general access machines, TASK 2.2: install on network, TASK 2.3 install on staff machines, TASK 2.4 install on home machines] | [Computer: software, architecture], rooms, network, TeamWave web site, servers | |
| Students (SA) | [TASK 2: Set-up groupware environment: TASK 2.4 install on home machines] | Computer, software, TeamWave web site, servers | Virus warnings |
| Technicians | [TASK 2: Set-up groupware environment: TASK 2.1: install on general access machines, TASK 2.2: install on network] | Computers, software, network, University policy | xDOS license expiry |
| Staff | [TASK 2: Set-up groupware environment: TASK 2.3 install on staff machines] | Office, timetable, computer | |

The researchers worked together to implement the TeamWave software using the available tools. The local interactions involved conducting the tasks of liasing with the technicians, downloading and installing the software, evaluating the implementation and forming new plans in the case of failure.

The South African students' interactions were relevant to Task 2.4 that involved downloading and installing the TeamWave system onto their home machines if they had access to one and if the machine had internet access. This involved connecting to the TeamWave web site, downloading the software, installing it and checking the connection.

The technicians assisted in the implementation in that they gave advice as to what could and could not be done based on their knowledge of the Wits University policy, the Wits computers and network and of the TeamWave system.

The study of local interactions has provided an insight into the erroneous situation involving the inability to achieve the intended implementation plans. A study of the situation and social context gives further details describing why they occurred in that specific way. Table 7.13 describes the situation context for this erroneous situation.

Table 7.13: Situation context for the TeamWave implementation failure

| Situation context involved with the error | | | |
|---|---|---|---|
| **Agents** | **Opportunities** | **Interests** | **Plans** |
| Researchers | [TeamWave: TeamWave software, TeamWave server, licenses, network, location, time], [Computers: Accessibility, software run from network, xDos licenses expired, no. of staff machines], Knowledge of Wits rules and procedures | Install and set-up software on general access machines, install on 9 machines | [Set up groupware environment: install on hard drive, install on network, install on staff machines, install on home machines] |
| Students (SA) | [TeamWave: TeamWave software, TeamWave server, licenses, network, location, time], [Computers: ownership, internet access] | Gain experience groupware systems, install software, security, cost | [Set up groupware environment: install on home machines] |
| Staff | Room availability, computer, timetable | Assisting the implementation, provide access when they are not using office | [Set up groupware environment: Give permission for office to be used when they are not using it] |
| Technicians | [skills: experience, Lack of knowledge of TeamWave], University procedures, no available server with internet access | Maintain computers, assist with TeamWave implementation | Assist installation |

The researcher group (Table 7.13) had knowledge of the TeamWave software and of the policies and procedures present at Wits. The intended implementation strategy could not be achieved and alternative plans had to be resorted to. This is indicated by the multiple plans, which will be a focus of the analysis. As new plans are required the interests of the researchers changes.

The students participated in the final contingency plan for implementing the groupware environment. Three students had computers with internet access in their homes and were able to install the TeamWave software on their home computers. The interest to install the software on their home machines was affected by their interest to save money and their concern over security.

The teaching staff in the Department of Psychology were not directly involved in the WitStaffs project but were keen to assist in the project by allowing the TeamWave software to be installed on their machines and for their offices to be used by the students to access the software.

The technicians' interest was to maintain the computers in the university but in terms of the WitStaffs project the plan was to assist in implementing the software. The technicians had little knowledge of groupware systems and no knowledge of the TeamWave software in particular.

Table 7.13 describes the situation context for the groupware implementation failure. This gives an insight into the opportunities, interests and plans of each participating group that are related to the implementation failure. Examining the social context can identify further factors that contributed to the failure Table 7.14 describes the social context for this error.

The social context table for the TeamWave implementation failure in Table 7.14 introduces higher level organisations into the error examination. These include the University of the Witswatersrand as a whole entity and the Department of Psychology as a separate sub-entity. The social context table introduces the goals, structures and history for each agent involved in the erroneous situation.

Table 7.14: Social context for the TeamWave implementation failure

| Social context involved with the error | | | |
|---|---|---|---|
| **Agents** | **Goals** | **Structures** | **History** |
| University of the Witswatersrand (Wits) | Educate students, promote distance learning research | University policy: to educate all races, to improve computer literacy], Limited computer resources | History of apartheid |
| Wits psychology department | Teach psychology, promote clinical research | Department culture, Limited computer resources, course option to learn about CSCW, timetable | History of apartheid |
| Researchers | Establish groupware environment for research | Research proposal | Previous successful implementation |
| Students (SA) | Experience groupware, write CSCW report based on experience | Timetable, telephone costs | Virus warning |
| Staff | To assist distributed learning research, not be inconvenienced | Timetable | |
| Technicians (SA) | Maintain computer resources | Policy of computer use | [Abuse of computer systems: theft, viruses], xDos not used for a long time |

A goal of the University of the Witswatersrand is to provide educational facilities to the students. They also have a goal to promote distance learning and computer-supported collaborative learning. In order to achieve this goal there are policies that are set to maintain high educational standards and the University provides resources such as literature, lecturers and computers to assist the students in their education. The structures at Wits have been subjected to much change due to the ending of apartheid in South Africa. Whereas in the past the education of black students was not encouraged, Wits are now enrolling many black students, many of whom have a limited knowledge of and access to technology due to their backgrounds. Black students are being taught subjects at university level that many white students had already learnt in schools.

The Psychology Department at Wits operates under the structures enforced by the respective universities. A goal of the department that has an impact on the collaborative human error is that they want to focus on clinical research as opposed to research in human factors or organisational behaviour. The department has limited computer resources. The emphasis on clinical research has also been influenced by the political history of South Africa.

The researchers' goal was to establish an international groupware environment for CSCW research. The structure set by the researchers to achieve these goals was the research proposal. Pilot studies had previously been conducted assessing the system's capability to support international collaboration but not to the extent that would test the eventual workload.

The goal of the students in SA was to write a report on CSCW with references to experiences gained from using the groupware system. The students were affected by structures such as their timetable and the cost of telephone calls inflicted by connecting to the TeamWave server. The students were also cautious of the Internet after a series of virus warnings had been distributed around the campus.

The goal of the technicians is to maintain the computer resources at their respective universities. The technicians set policies regarding the use of the machines. These policies dictate how the machines are set up, what they are used for and what software is installed on them. The technicians at Wits have experienced security problems in terms of computer components going missing and in terms of unauthorised access to the computers. Due to this history the technicians at Wits have enforced very strict structures in regards to security.

This section has described the contexts that were present in this error example. The section has indicated some areas where conflicts between contextual elements may exist. The following section describes the classification and description of the events in this error example.

#### 7.3.1.3 Error Classification and Description

This section describes the error classification and description for the TeamWave implementation failure (Appendix C4.1). The section describes the classifications according to each level of context starting with the level of local interactions, followed by errors at the level of situation context and then errors at the level of social context.

The errors at the level of local interaction can be seen in the following error list:

1) TASK2: Technicians(KB-TOOL: software, TeamWave)
2) TASK2.1: Researchers(RB-TASK: Install on general access machines)
3) TASK2.1: Researchers(KB-TOOL: computer: architecture)
4) TASK2.2: Technicians(KB-EVENT: xDOS license expiry)
5) TASK2.4: Students SA(KB-EVENT: virus warning)

The above error list for local interactions describes how the technicians do not have previous knowledge of the TeamWave software (1) or its architecture. The researchers make a rule-based error in selecting to install the software on the hard drives of the general access machines (2). This rule-based error arises from a lack of knowledge about the architecture of the general access computers (3). The researchers then decide to install the software on the network. This would have been a workable option if the technicians hadn't made a knowledge-based error of the xDos license expiry date (4). The students were cautious about downloading the software because of virus warnings that had been circulating the university (5).

The errors of situation context can be seen in the following error list:

6) TASK2.1: Researchers(PL: install on hard drives)-(OP: Computers: software run from network))
7) TASK2.2: Researchers(PL: install on network)-Technicians(OP: technicians(OP: Skills: Lack of knowledge of TeamWave)
8) TASK2.1: Researchers(PL: assist with TeamWave implementation)-Technicians(OP: no available server with internet access)
9) TASK2.2: Researchers(PL: install on network)-(OP: Computers: xDos licenses expired)
10) TASK2.3: Researchers(PL: install on staff machines)-OP(Computers: no. of staff machines)
11) TASK2.3: Researchers(PL: install on staff machines)-Staff (OP: room availability)
12) TASK2.4: Researchers(PL: install on home machines)-Students SA(OP: experience, virus warning)
13) TASK2.4: Researchers(PL: install on home machine)-Students SA(INT: cost, security)
14) TASK2.4: Researchers(PL: install on home machine)-Students SA(OP: no computer)

The above error list for situation context describes how the researchers' plan to install the TeamWave software on general access machines was affected by the fact that all general access software was run from a central server (6). The technicians' lack of knowledge of the TeamWave application meant that they were not sure how they could set this type of software to run from a server that had access to the Internet (7). This was impeded by the fact that the technicians could not allow the software to be run on a server with internet access (8). The second option to install the software on a server run by the psychology department was prevented by the expiry of the xDos software that was used to run the TeamWave Clients on remote computers (9). After these two attempts a compromise plan had to be formed that involved installing the TeamWave software on staff machines and on students' own home machines. Unfortunately there were not enough staff machines for all students (10) due to the availability of the offices (11). Students were reluctant to install the software on their machines due to a recent virus warning (12) and the cost and security of connecting to the Internet (13). Not all students could install the software on their home computers because they did not own one (14).

The errors of social context can be seen in the following error list:

15) TASK 0: Wits(GL: promote distance learning research)- Wits Psychology Dept.(GL: promote clinical research)
16) TASK2: Researchers(GL: establish groupware environment)-Wits(STR: Limited computer resources)
17) TASK2: (researchers(GL: establish groupware environment)-Wits psychology(GL: promote clinical research))
18) TASK2: Researchers(GL: establish groupware environment)-Wits Psychology Dept.(STR: Limited computer resources)
19) TASK2: (Researchers(GL: establish groupware environment)-(HIS: Previous successful implementation)
20) TASK2.1: Researchers(GL: establish groupware environment)-Technicians(HIS: Abuse of computer systems: theft, viruses)
21) TASK2.2: Researchers(GL: establish groupware environment)-Technicians(HIS: xDos not used for a long time)
22) TASK2.3: (Researchers(GL: establish groupware environment)-Staff (GL: Not to be inconvenienced)

The above error list for social context describes how a goal of Wits was to promote the development of distance learning technology but the priority of the psychology department was to promote clinical research (15). All of the remaining social context errors focus around the researchers' goal to set up the groupware environment. Other collaborative human errors do exist but they are out of the scope of this examination. The goal to set up the groupware environment was impeded by a number of factors. These include the lack of computer resources in the psychology department (17) and the university as a whole (16). The priority of the psychology department was to focus on clinical rather than human factors research (18). The goal was also impeded by the prior expectations of the researchers when implementing the TeamWave software due to the relatively easy implementation of the software at Staffordshire University (19). The recent history of computer abuse and the recent virus warning meant that the general access computers and the network were under strict security (20). The expiry of the xDos software license occurred because it had not been used for a long time and was not deemed to be useful anymore (21). The final factor at the level of social context was that the lecturing staff did not want to be inconvenienced by the students using the software in their offices (22).

This section has described the error classification and descriptions of the events contributing to the TeamWave implementation failure example error. The following section describes an analysis of the error.

#### 7.3.1.4 Error Analysis

The previous section described the classifications that described the failures to implement the TeamWave software. The classifications show that common classification elements make up the descriptions at each level. This section examines what the classifications say about the failure under examination.

The level of local interactions are classified solely by rule-based errors where inappropriate rules are selected by an incomplete or inaccurate knowledge. The researchers had no knowledge of the architecture of the general access machines and the technicians had no knowledge of the TeamWave software which impeded their ability to assist the researchers. As a result the technicians suggested xDos was used as a tool to connect to TeamWave clients from a server with internet access. Knowledge-based errors were made by the technicians regarding the xDos license expiry date and the students did not have a detailed knowledge of viruses and how they spread.

The errors at the level of situation context consist entirely of classifications including the planning element. The classification describes how each plan formulated by the researchers was impeded or prevented, in most cases, by inappropriate opportunities. This either means that the initial plans of the researchers were ineffective or the opportunities were not present for some reason. The level of social context helps to determine why the plans were selected and why the opportunities were present.

The classifications at the level of social context describe how the goal of the researchers was impeded by structures and historical factors. The turbulent history of South Africa and the University of the Witswatersrand meant that structures were put into place to tackle crime and virus attacks. The researchers had also experienced a relatively trouble-free implementation of the TeamWave software at Staffordshire University. This led to the belief that implementing the software at Wits would also be unproblematic. The impact of the historical elements reduced the opportunities to realise their plans. These risks were anticipated but were thought to be addressable.

This section has described the data organisation, classification and description and analysis of the groupware implementation failure example error. The following section describes a further example of collaborative human error occurring in the WitStaffs study.

### 7.3.2 Conflict over Tools in a Shared Workspace

The following sections describe the organisation of the data, the error classification and the error analysis for the conflict of tools in a shared workspace error according to the requirements of the application framework. This error occurred during a conflict resolution task that was set for the students by the researchers.

This collaborative human error involved the use of the TeamWave workspace. The error occurred in a groupware tutorial involving ten final year students who were using the TeamWave workspace to discuss their assignment. The ten students were split into two groups of five with each group working in different rooms. Within the room the students had access to a number of tools that they could utilise for the purpose of the discussion. The error occurred when two tools used for the discussion were placed in the same location on the workspace and two users wanted to use both tools at the same time. This had the effect that when one tool was being used it was placed into the foreground and the second tool was placed into the background. When both agents were trying to use both tools at the same time they were fighting over which tool should be in the foreground.

### 7.3.2.1 Data Collection

The data for this study was collected through observations of the participant's interactions and communication. The participants were split into two groups, each group performing the same task in two different virtual rooms. Three researchers were used to observe the sessions. One researcher observed Room 1; a second researcher observed Room 2; and the third acted as a trouble-shooter should the participants experience any difficulties. After the session each participant was interviewed individually and asked questions on their experiences.

### 7.3.2.2 Organising the Data

The task analysis for the task under investigation can be seen in Figure 7.6 and the tasks are reflected in the local interaction context table seen in Table 7.15. This section describes the organisation of the data relating to local interactions, situation and social context that is specific to this error example (Appendix C3.2).

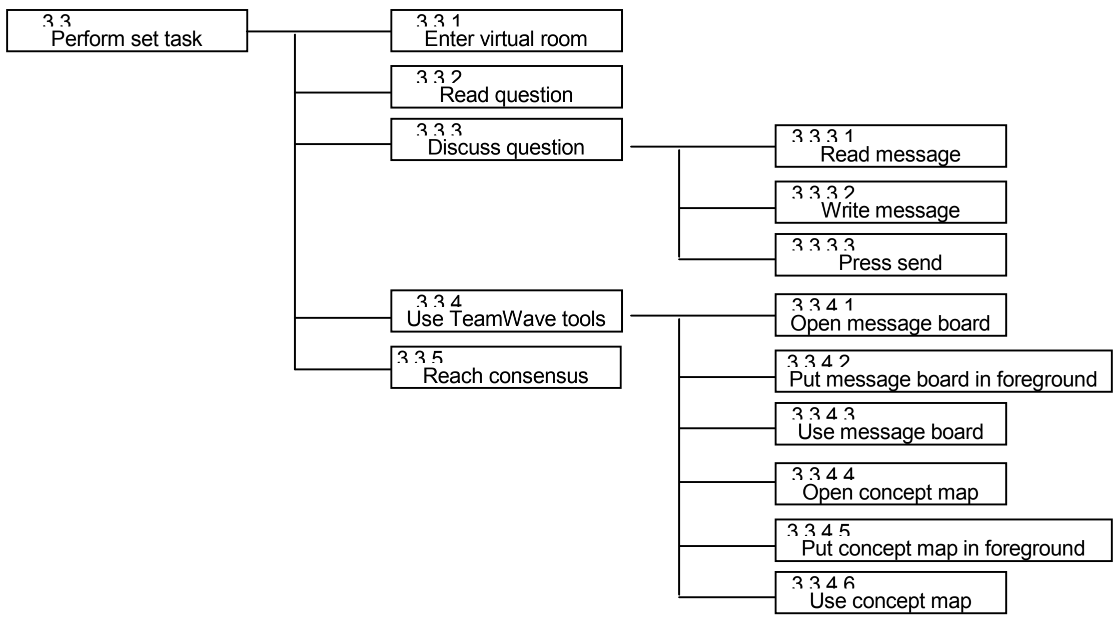


Figure 7.6: Task analysis for the implementation of the TeamWave environment

During the use of the TeamWave software two students experienced an erroneous situation involving a conflict over tools in the shared workspace. The task analysis in Figure 7.6 shows the sequence of actions that led to the erroneous implementations of the WitStaffs groupware environment.

The erroneous situation is described in the sub-tasks of task 3.3 (Figure 7.6). This task grouping describes how two tools were opened and how they were brought into the foreground in order for them to be used. Task 3.1, task 3.2 and task 3.4 describe the tasks surrounding the erroneous tasks to place them in context.

The context tables below consider only the two students involved in the conflict. The other students in the group are not included in the analysis because they had no direct influence within the scope of this study.

The context table in Table 7.15 describes the local interactions specific to the conflict over shared tools as described the task analysis in Figure 7.6.

Table 7.15: Local interaction table for conflict over tools in shared workspace

| Local interactions involved with the error | | | |
|---|---|---|---|
| **Agent** | **Task** | **Tool** | **Event** |
| Student 1 | [Use TeamWave features: open message board, bring message board into foreground, use message board] | [TeamWave: workspace, message board, concept map, text chat] | |
| Student 2 | [Use TeamWave features: open concept map, bring concept map into foreground, use concept map] | [TeamWave: workspace, message board, concept map, text chat] | |

There are two agents involved with this example error and the tasks that they perform are reflected in the task analysis in Figure 7.6. The tools that they use are grouped together because they are all part of the overall TeamWave application. The difference between the two agents is that the tasks of one agent are focused around the message board tool and the tasks of the second student are focused around the concept map tool.

The local interaction table describes how each agent was attempting to perform tasks using different tools in the same location. A study of the situation and social context gives further details describing why they occurred in that specific way. Table 7.16 describes the situation context for this erroneous situation.

Table 7.16: Situation context table for conflict over tools in shared workspace

| Situation context involved with the error | | | |
|---|---|---|---|
| **Agent** | **Opportunities** | **Interest** | **Plans** |
| Student 1 | [TeamWave: tools in same location, workspace bigger than screen, message board, concept map, text chat] | Place message on message board, not in moving concept map, not in forming a consensual plan | [Perform set task: Use TeamWave features: Open message board, bring message board into foreground, Use message board] |
| Student 2 | [TeamWave: tools in same location, workspace bigger than screen, message board, concept map, text chat] | See what concept map does, not in moving message board, not in forming a consensual plan | [Perform set task: Use TeamWave features: open concept map, bring concept map into foreground, use concept map] |

The situation context table (Table 7.16) describes how both students had the same opportunities but their interests and the subsequent plans that were formed are very different. Student 1 wanted to place a message whilst Student 2 wanted to use the concept map. There was no interest to move a tool to a different location so that both tools could be used independently or to reach an agreement as to which tool they would use at that particular time.

Table 7.16 describes the situation context for the conflict over tools in the shared workspace error example. This gives an insight into the opportunities, interests and plans of each participating group that are related to the failure. Examining the social context identifies further factors that contributed to the failure. Table 7.17 describes the social context for this error.

Table 7.17: Social context table for conflict over tools in shared workspace

| Social context involved with the error | | | |
|---|---|---|---|
| **Agent** | **Structure** | **Goal** | **History** |
| Student 1 | Group protocol, task instructions, TeamWave functionality | reach consensus with group, log discussion points using the message board | |
| Student 2 | Group protocol, task instructions, TeamWave functionality | Reach consensus with group, explore TeamWave tools | |

The social context table (Table 7.17) describes how both students are working under the same structures, and have a common goal to reach consensus on the discussion topic. The table also shows that Student 1 wants to use the message board as a tool to discuss the discussion topic whereas Student 2 has a separate goal to explore the features of the TeamWave system. There were no apparent historical elements involved in this erroneous situation.

This section has described the contexts that were present in this error example. The following section describes the classification and description for this error example.

#### 7.3.2.3 Error Classification and Description

This section describes the error classification and description for the conflict over tools in a shared workspace error example (Appendix C4.2). The section describes the classifications according to each level of context starting with the level of local interactions, followed by errors at the level of situation context and then errors at the level of social context.

The errors at the level of local interaction can be seen in the following error list:

1) TASK 3.3: Student 1(RB-TASK: use message board)
2) TASK 3.3: Student 1(KB-USER: Student 2)
3) TASK 3.4: Student 2(RB-TASK: use concept map)
4) TASK 3.4: Student 2(KB-USER: Student 1)
5) TASK 3: Student 2, Student 1(KB-TOOL: workspace)

This error description describes how Student 1 made a rule-based error in selecting to use the message board when Student 2 was trying to use the concept map tool (1). This was contributed to by the lack of knowledge of Student 2's intention (2). Likewise, Student 2 makes a rule-based error in selecting to use the concept map when Student 1 was trying to use the message board (3). This was contributed to by the lack of knowledge of Student 1's intention (4). Knowledge-based errors were also made by both students in that they did not appreciate that the workspace was larger than the space displayed on their screen (5) which would have allowed both tools to be used consecutively.

The errors at the level of situation context can be seen in the following error list:

6) TASK 3: Student 1 (INT: Place message on message board)-Student 2(INT: See what concept map does)
7) TASK 3: Student 1(PL: bring message board into foreground)-Student 2(PL: bring concept map into foreground)
8) TASK 3: Student 1(PL: use message board)-Student 2 (INT: See what concept map does)
9) TASK 3: Student 2(PL: use concept map)-Student 1 (INT: Place message on message board)
10) TASK 3: Student 1(PL: use message board)-(OP: concept map)
11) TASK 3: Student 2(PL: use concept map)-(OP: message board)
12) TASK 0: Student 1(PL: bring message board into foreground)-(INT: Not in moving concept map)
13) TASK 0: Student 2(PL: bring concept map into foreground)-(INT: Nit in moving message board)
14) TASK 0: Student 1, Student 2 (PL: Perform set task: Use TeamWave features) – (INT: not in forming a consensual plan)

The above error list describes initially how the two students had different interests in using the TeamWave Workspace (6). These interests were realised in two conflicting plans being attempted to bring a tool into the foreground (7) above the tool the agent was trying to use. The plan of each student to use their respective tool was disrupted by the other student's interest (8 and 9). These two conflicting plans led to inappropriate opportunities existing because the two tools were overlaying each other preventing the underlying one from being used (10 and 11). There was no interest in moving the tools so they didn't overlay each other (12 and 13) and there was no interest in forming a plan of action that both students consented to (14).

The errors at the level of social context can be seen in the following error list:

15) TASK 0:Student 1(GL: log discussion points using the message board)-Student 2(GL: explore TeamWave tools)
16) TASK 0:Student 1, Student 2(GL: reach consensus with group)-(STR: group protocol)
17) TASK 0: Student 1, Student 2(GL: reach consensus with group)-(STR: TeamWave functionality)

This error list describes how the two students had conflicting goals (15) as reflected in the plans and interests at the level of situation context. The overall goal to reach a group consensus, in the scope of this error example, was impacted by the group protocol being ineffective (16) in some way and the features of the TeamWave software being ineffective at facilitating this type of discussion (17).

This section has described the error classification and descriptions of the events contributing to the conflict over tools in a shared workspace example error. The following section describes an analysis of the error.

#### 7.3.2.4 Error Analysis

The previous section described the classifications that described the conflict of tools in a shared workspace. The classifications show that common classification elements make up the descriptions at each level. This section examines what can be inferred from the classifications about the erroneous situation.

At the level of local interaction there is a combination of rule-based and knowledge-based errors involving the way that the students interact with the tool and with each other. The students made rule-based errors because they did not know what the other students' intentions were and they had an incorrect perception of the size of the workspace.

All of the error descriptions at the level of situation context consist entirely of classifications including the plan element with the exception of the initial interest-interest error. The description also illustrates how interests manifest themselves as plans and how the plan creates adverse opportunities. The description also illustrates how the lack of certain interests that could have been considered in a possible correct task sequence impacted upon the plans being carried out effectively.

The errors at the level of social context describe conflicting goals and non-optimal structures that contributed in some way to the error. The description identifies that the group dynamics were not effective. Lower level classifications illustrate this in that the two students had different interests and attempted to carry out conflicting plans. The final classification describes how the TeamWave software could have limited the student's ability to discuss the topic. This, again, is illustrated at lower levels of classification.

This section has described the error description and analysis of the conflict over tools in a shared workspace error example. The following section describes a further example of collaborative human error from the WitStaffs study.

### 7.3.3 Agents Joining an Incorrect Workspace

The following sections describe the organisation of the data, the error classification and the error analysis for the agents joining an incorrect workspace error according to the requirements of the application framework. This error occurred during a conflict resolution task that was set for the students by the researchers.

In this groupware session there were two groups each containing four agents. In one of the groups there was a lot of discussion and in the other group there was much less. Some of the agents in the group experiencing little communication in the first room moved to the group experiencing a high-level of communication in the second room. This error occurred during the discussion about the statement regarding the death penalty described in the first part of this chapter.

#### 7.3.3.1 Data Collection

The data collection for this study used the same approaches as for the examination of the previous example error in Section 7.3.2.

#### 7.3.3.2 Organising the Data

The data is organised using a task analysis and a series of context tables. The task analysis for the error under investigation can be seen in Figure 7.7 and the tasks are reflected in the local interaction context table seen in Table 7.18. This section describes the organisation of the data relating to local interactions, situation and social context that is specific to this error example (Appendix C3.3).

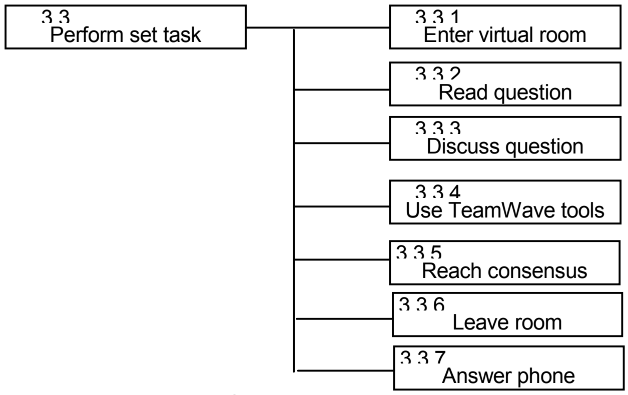

Figure 7.7: Task analysis for the agents joining an incorrect workspace error

The task analysis describes the sequence of tasks from task 3.3 involved in this erroneous situation. The sequence does not appear to involve any errors but the errors occur due to the sequence in which the tasks are performed. Some agents decide to leave the room and enter a different room after an evaluation of situation. Table 7.18 describes the local interaction context for this example error.

Table 7.18: Local interaction table for the agents joining an incorrect workspace error

| Local interactions involved with the error | | | |
|---|---|---|---|
| **Agent** | **Task** | **Tool** | **Event** |
| Group1a: Student 1, Student 2 | [Perform set task: Enter room, use teamwave tools, discuss question, evaluate situation, reach consensus, leave room] | [TeamWave: room1, room2, doorway, workspace, text chat] | |
| Group1b: Student 3, Student 4 | [Perform set task: Enter room, use TeamWave tools, answer phone, discuss question, evaluate situation, reach consensus] | [TeamWave: room1, workspace, text chat] | |
| Group2 | [Perform set task: Enter room, use teamwave tools, discuss question, evaluate situation, reach consensus] | [TeamWave: room2, workspace, text chat] | |

The agents have been split into three groups. Group1a refers to the agents working in room1 who moved to room2. Group1b refers to the agents in room 1 who remained in room1. Group2 refers to the four agents who were working in room 2. Each agent has exactly the same tools to work with. The tasks that they all perform are the same with the exception that group1a performs the task to leave the room.

The local interaction table describes how the students in Group1a decided to leave the room to which they were assigned. Table 7.19 describes the situation context for this erroneous situation.

Table 7.19: Situation context table for the agents joining an incorrect workspace error

| Situation context involved with the error | | | |
|---|---|---|---|
| **Agent** | **Opportunities** | **Interest** | **Plans** |
| Group1a: Student 1, Student 2 | [TeamWave: room1, room2, doorway, workspace, text chat], lack of communication, no. of agents | Complete the task, participate in discussion | [Perform set task: Enter room, use TeamWave tools, discuss question, evaluate situation, reach consensus, leave room] |
| Group1b: Student 3, Student 4 | [TeamWave: room1, room2, doorway, workspace, text chat], no. of agents, using home computer, telephone call | Complete the task, telephone call | [Perform set task: Enter room, use teamwave tools, discuss question, evaluate situation, reach consensus] |
| Group2 | [TeamWave: room1, room2, text chat], [no. of agents] | Complete the task, participate in discussion | [Perform set task: Enter room, use TeamWave tools, discuss question, evaluate situation, reach consensus] |

The situation context table (Table 7.19) shows that Group1b was distracted by opportunities arising that were not relevant to the groupware task. In this case both students were distracted by telephone calls. This resulted in their interests being temporarily focused on the telephone call rather than contributing to the discussion. The lack of communication experienced by Group1a led to the decision to change rooms to the other room where more active discussions were taking place.

Table 7.19 describes the situation context for the conflict over tools in the shared workspace error example. Table 7.20 describes the social context for this error.

Table 7.20: Social context table for the agents joining an incorrect workspace error

| Social context involved with the error | | | |
|---|---|---|---|
| **Agent** | **Structure** | **Goal** | **History** |
| Group1a | Group protocol, task instructions, TeamWave functionality, groupware environment set-up | Experience groupware environments, Reach consensus, find an active discussion | |
| Group1b | Group protocol, task instructions, TeamWave functionality, groupware environment set-up | Experience groupware environments, Reach consensus | |
| Group2 | Group protocol, task instructions, TeamWave functionality | Experience groupware environments, Reach consensus | |

The social context table (Table 7.20) makes reference to the groupware environment set-up that may have been inappropriate to achieve the goals of the students within the group. There is also a reference to the goal of Group 1a to find an active discussion.

This section has described the contexts that were present in this error example. The following section describes the classification and description for this error example.

#### 7.3.3.3 Error Classification and Description

This section describes the error classification and description for the agents joining an incorrect workspace error example (Appendix C4.2). The section describes the classifications according to each level of context starting with the level of local interactions, followed by errors at the level of situation context and then errors at the level of social context.

The errors at the level of local interaction can be seen in the following error list:

1) TASK 4: Group1b(RB-TASK: answer phone)
2) TASK 0: Group1b(KB-USER: group1b)
3) TASK 7: Group1a(RB-TASK: leave room)

This error list for local interaction states that agents in Group1b made a rule-based error as far as the groupware task was involved, to answer the phone (1) and not participate in the discussion task. Agents in group1a did not have any knowledge as to the reason why there was no communication from Group1b (2). Agents in Group1a then made a rule-based error when selecting the task to leave room 1 (3).

The errors at the level of situation context can be seen in the following error list:

4) TASK 0: Group1a(INT: participate in discussion)-Group1(OP: lack of communication)
5) TASK 0: Group1a(INT: participate in discussion)-Group1b(INT: telephone call)
6) TASK 0: Group1(PL: perform task)- Group1b(INT: telephone call)
7) TASK 0: Group1(PL: perform task)-group1a(PL: leave room)
8) TASK 0: Group1b(PL: perform task)-(OP: no. of agents)
9) TASK 0: Group2(PL: perform task)-(OP: no. of agents)
10) TASK 0: Group2(OP: TeamWave)-(OP: no. of agents)

This error list of situation context errors describes how the interest of Group 1a to perform the set task was disrupted by the lack of communication that was present (4). Group 1a's interest to participate in the discussion was inhibited by the fact that the interest of Group 1b was to talk on the telephone (5). This interest meant that the plan to perform the task was not achievable (6). The plan of Group 1a to leave the room impacted further upon the inability of the plan to perform the task to be achieved (7) because there were too few agents remaining in the room to complete the task (8). The fact that Group 1a joined Room 2 meant that there were too many agents in room 2 to perform the task (9). The TeamWave software was not optimal for catering for more than six participants (10).

The errors at the level of social context can be seen in the following error list:

11) TASK 0: Group1(GL: reach consensus)-(STR: groupware environment set-up)
12) TASK 0: Group1(GL: reach consensus)-(STR: group protocol)
13) TASK 0: Group2(GL: reach consensus)-Group 1a(GL: find an active discussion)

This error list for social context describes how the goal of Group1 was to reach a consensus but was impeded by the groupware environment set-up (11) and the group protocol that existed (12). The goal of group 2 to reach consensus was affected by the goal of Group 1a to find an active discussion (13).

This section has described the error classification and descriptions of the events contributing to the agents entering an incorrect workspace example error. The following section describes an analysis of the error.

#### 7.3.3.4 Error Analysis

The previous section described the classifications that described the agents entering an incorrect workspace example error. This section examines what can be inferred from the classifications about the erroneous situation.

At the level of local interactions there are rule-based and knowledge-based errors. The rule-based errors include the decision to answer and talk on the phone and the decision of Group1a to leave the room. The rule-based error is only an error in the context of the groupware task but not necessarily in other contexts relevant to the group. The knowledge-based error arises because Group 1a has no knowledge that Group 1b are talking on the phone.

The classifications at the level of situation context describe how the priority of interest of Group 1b changes as they talk on the phone. This impacts upon the opportunities for Group 1a to complete the set task and formulate plans based on their interests. This results in non-optimal opportunities being created for both groups due to the lack of communication and the distribution of participants in each room.

The classifications at the level of social context show that there is an inappropriate groupware environment set-up in that two of the participants were working from home. The examination in Section 7.3.1 describes why this set-up occurred but it remains inappropriate for the groupware task. The relationships existing within the group due to the participants leaving the room also impeded the goal to reach a consensus.

This section has described the data organisation, classification and description and analysis of the agents entering an incorrect workspace example error. The following section describes the contribution to the research provided by this study and the other studies described in this chapter.

## 7.4 Examination of the Classification Model

This section describes how the examination of the example errors in the previous sections has contributed to this research. The section first describes the overall contribution to research then describes the issues and problems that were identified through the study. The section then describes alterations that could be made to the classification model in future work.

### 7.4.1 Addressing the Research Objectives

The previous sections described how the classification model was applied to each example error from the diagram building task. From this examination a number of issues were identified with the classification model and the method by which it was applied. This section describes the contribution to the research by reviewing the objectives of the study specified in Chapter 5.

1) To examine erroneous situations where all aspects of the model can be used to examine collaborative human errors;
2) To further addresses the problems of paper-based case studies identified by Reason by applying the classification model to observed examples of human error;
3) To further contribute to a corpus of low-level errors that could be examined using the classification model;
4) To further examine the application of the classification model and the changes made to it as a result of Phase 2; and
5) To further suggest changes to the classification model and application framework.

The initial studies of this research described in Chapter 6 of this thesis were restricted in the sense of the limited amount of data that could be gathered about the local interactions that occurred. This meant that the studies had to focus on aspects of social and situation context. To address this issue the studies described in the first section of Chapter 7 examine errors occurring within an experimental groupware environment. This enabled the detailed capture of data relating to local interactions and situation context but restricted the data that could be captured relating to social context. The studies described in the previous section of this chapter describe the application of the classification model and application framework on errors observed within the implementation and use of the WitStaffs groupware environment. This enabled the capture of data relating to all aspects of the model which is reflected in the description of the study in Section 7.3.

The WitStaffs study was conducted with the author of this thesis participating in and observing the implementation and use of the WitStaffs groupware environment. This meant that the completeness and accuracy of the data collected was known to the researcher. The nature of the study meant that the researcher had an accurate understanding of the complex events involved in the collaborative human error from the different viewpoint of each participant. This meant that the errors examined from the WitStaffs study used the full range of data relevant to the model of collaborative human error.

The studies described in this section further contributed a more diverse set of error types to the corpus of errors. The errors that were observed in the WitStaffs study were of a similar type to the examples seen in the large case studies such as LASCAD and the examples seen in the diagram building study. This meant that a broad range of error types was maintained within the corpus of errors collected in this research including errors involving organisations and groups and a large degree of latency to errors involving individuals and lower levels of latency.

The diagram building study described earlier in this chapter resulted in a number of changes to be made to the classification model and application framework. These changes, in addition to the changes from the LASCAD study not testable in the previous studies, were implemented in the examination of the WitStaffs example errors. The changes are discussed in the following:

1) The increased amount of data that could be obtained about the erroneous situations meant that the situation could be examined using the model in different ways. This change was initiated in the examination of the diagram building task and was continued in the examination of the WitStaffs study. Comparing a task analysis of the erroneous situation to a task analysis of a correct sequence of actions meant that a more complete understanding was seen of the task sequences involved in the erroneous situation (Change 3.1).
2) The studies in Chapter 6 adopted a top-down approach to applying the classification model which was selected due to the limited amount of local interaction data available. In the diagram building study a bottom-up approach was applied because of the limited amount of social context data. In the WitStaffs study it was seen that the direction of application depended on the nature of the erroneous situation. Erroneous situations such as the selection of the suppliers in the LASCAD study and the implementation of the groupware environment in the WitStaffs study warrant a top-down approach whereas low-level errors warrant a bottom-up approach (Change 3.2).
3) The diagram building task illustrated the need for techniques to gather social context data relating to individuals. In the WitStaffs study this data was collected through a combination of interviews and focus groups (Change 3.3).
4) The application of the classification model to errors observed in the WitStaffs study demonstrated a more complete understanding of collaborative human errors as specified in change 3.4. For example, error latency was illustrated in the final error example where the distraction of the phone call created a work environment unsuitable for completing the task set. The error descriptions from each study were examined in terms of the type of erroneous situation and the error classifications that form the error description to see if any patterns existed.
5) The error descriptions that were formed in this study illustrate how the hierarchical structure of the contextual elements within the context tables can be transferred into the error notation (Change 3.5). The new format of the descriptions illustrates how they are more structured but still maintains their readability.
6) In the diagram building study the size of the example errors meant that the question of who was responsible for a contextual element at the level of social context was

not relevant. This meant that Change 2.8 resulting from the LASCAD study could not be tested. The WitStaffs study demonstrated the assignment of contextual elements at the level of social context according to who was responsible for them existing in the erroneous situation. This distinction made it easier to form the context tables and to identify causal paths outside of the current scope of examination.

7) In the diagram building task the errors examined involved individuals and not groups or organisations. This meant that the problem of contextual elements applying to groups differing from those belonging to their constituent members was not applicable. This meant that Change 2.10 from the LASCAD study could not be tested. It is believed that preventing this issue from arising can only be achieved by breaking every examination of collaboration down to the individual agents involved rather than abstracting from groups. The time involved in doing this and the complexity of the analysis is unreasonable which means that the problem must be considered when conducting an examination but it is a requirement to deal with groups and organisations.

Through this research the classification model has been developed to create an understanding of the occurrence of collaborative human error. Throughout the research the main focus has been on developing an understanding of the causes and reasons for collaborative human error occurrence. There are a number of further areas that were out of the scope of this research but are important to consider in future research studies. These areas are introduced and potential areas for further work are proposed. Table 7.21 summarises the problems identified from these studies and some areas not included in the scope of this research and the areas of future work that could be conducted to address them.

Table 7.21: Problems and solutions resulting from the example errors

| Change No. | Problems | Potential Solutions |
|---|---|---|
| 4.1 | Using the error descriptions for empirical analysis | The classification model needs to be developed further and applied to a larger corpus of collaborative human error examples for its validity as a tool for empirical analysis of erroneous situations and potential erroneous situations. |
| 4.2 | Need for a more rigorous method for applying the classification model | Work is required to develop and validate a structured method for rigorously applying the classification model. |
| 4.3 | The classification model only addresses aspects of causality but does not address aspects of recovery | Extending the model to address aspects of collaborative error recovery |
| 4.4 | Lack of understanding of why certain patterns exist for certain erroneous situations | Use the classification model to learn more about the occurrence of collaborative human error and conclusions that can be drawn from the classification make-up of an erroneous situation. |
| 4.5 | The research does not address how the classification model can be used to contribute towards error defences. | Use a structured method to perform a more detailed analysis of further examples of collaborative human error of all sizes to enable more extensive conclusion to be drawn. |
| 4.6 | The process of forming the error classifications and descriptions takes a long time. | Produce software to assist the creation of the error descriptions and automate the analysis process. |

Table 7.21 describes the main problems if the classification model and how these problems were addressed through implementing changes. Each of these problems and changes are described in more detail in the following sections.

### 7.4.2 Problems Identified Through the Research

The previous section described the contribution to research provided by the examination of the example errors. This section gives a more detailed description of the problems and issues experienced when using the classification model to provide an understanding of collaborative human error in relation to the example errors. The following section describes the changes and considerations that resulted from this study. The problems and issues experienced from this study are listed in Table 7.22.

Table 7.22: Table identifying the problems of the classification model identified from the collaborative diagram building study

| Problem No. | Description |
|---|---|
| 4.1 | Limited ability to draw conclusions from the studies through a lack of empirical evidence. |
| 4.2 | Need for a more rigorous method for applying the classification model |
| 4.3 | The classification model only addresses aspects of causality but does not address aspects of recovery |
| 4.4 | Lack of understanding of why certain patterns exist for certain erroneous situations |
| 4.5 | The research does not address how the classification model can be used to contribute towards error defences. |
| 4.6 | The process of forming the error classifications and descriptions takes a long time. |

Table 7.22 gives a brief description of the problems of the classification model identified from the example errors. Each of these problems is described in the points below.

***Problem 4.1:*** The ability to draw conclusions about the example errors examined in this research has been limited. This is because of the limited corpus of error examples that were examined. The analysis of collaborative human errors was not in the scope of this research and thus the application framework did not support a comprehensive analysis phase. These factors restricted the ability to conduct an empirical analysis of the erroneous situations.

The analysis that has been conducted in the studies reported in this thesis has been based on qualitative assessments from the understanding of the error occurrence gained from the examination. The examination does provide a more structured understanding of the occurrence of collaborative human errors but there is not enough data to allow prediction or to provide tools to assist the examination of these errors through empirical means.

*Problem 4.2:* Up to this point the classification model has been applied using an application framework developed from tools used in traditional human factors approaches and error analysis methods. This application framework was useful in developing the classification model and in developing an understanding of collaborative human errors. However, the approach may not be the optimal approach to take for applying the classification model. Developing an optimal method for applying the classification model was not an objective of this research.

*Problem 4.3:* The classification model only address aspects of causality but does not address aspects of recovery. Through applying the classification model it has been possible to obtain a good understanding of the mechanisms involved in the causes of erroneous situations through collaborative human error. However, the classification model did not extend to address the mechanisms of recovering from a collaborative human error. Considering recovery mechanisms in the model would enable approaches to be developed to reduce the criticality of the consequences of a collaborative human error.

*Problem 4.4:* The studies in this research indicated potential links between the dominant classification types that describe an erroneous situation and the type of erroneous situation itself. However, the corpus of errors was not big enough to fully test this hypothesis. The identification of these potential patterns was initiated in the examination of the WitStaffs study but the number of studies conducted in this research has not been sufficient to address this observation and what can be concluded from it. Gaining a more complete understanding of these patterns may provide useful information relating to error prediction and the design of error defences.

*Problem 4.5:* The research does not address how the classification model can be used to contribute towards the design of error defences. Although the research helps to develop an understanding of why collaborative human errors occur the classification model does not extend to supporting the design of error defences to reduce the likelihood of an error occurring or reduce the criticality of its consequences.

*Problem 4.6:* The process of forming the error classifications and descriptions takes a long time. Throughout the studies the process of forming the error descriptions has been a time-consuming process. The time involved in forming the error description may be a major factor in the adoption of this approach to human error. The improved structure of the application has improved the process to some degree but more work needs to be conducted to further speed the process up.

This section has described the problems that were experienced during this research and problems outside of the research scope. The following sections describe the potential changes to the classification model and areas of further work to address these problems.

### 7.4.3 Future Changes to the Classification Model

The classification model and application framework applied and developed in this chapter have resulted in a novel approach for examining human errors in collaborative environments. The research described throughout this thesis has illustrated a model of collaborative human error and how it can be classified and described. The application framework has provided a structured approach for the application of the classification model on the case studies. This section describes potential areas for future work that have arisen as a result of the studies described in this chapter as summarised in Table 7.23.

Table 7.23: Table showing future changes resulting from Phase 3

| Future Change No. | Description |
|---|---|
| 4.1 | The classification model needs to be developed further and applied to a larger corpus of collaborative human error examples for its validity as a tool for empirical analysis of erroneous situations and potential erroneous situations. |
| 4.2 | Work is required to develop and validate a structured method for rigorously applying the classification model. |
| 4.3 | Extending the model to address aspects of collaborative error recovery |
| 4.4 | Use the classification model to learn more about the occurrence of collaborative human error and conclusions that can be drawn from the classification make-up of an erroneous situation. |
| 4.5 | Extend the use of the classification model to assist in the design of error defences against collaborative human errors. |
| 4.6 | Produce software to assist the creation of the error descriptions and automate the analysis process. |

Each of the alterations in Table 7.23 is discussed in relation to how it addresses each of the problems listed previously.

*Future Change 4.1: Extending the research to include a more extensive analysis facility*

The research described in this thesis has not examined a sufficiently large enough corpus of errors to enable the development of tools to support a comprehensive analysis of the error descriptions created as a result of applying the classification model. Using a more comprehensive corpus of errors would enable the analysis to address issues of error prediction, error explanation and error remedy. In addition the approach could support case-based reasoning for applications such as improving the indexing and retrieval of accident and incident reports (Johnson 2000).

In order to extend the research to enable a comprehensive analysis the classification model needs to be applied to a much larger corpus of error examples. This would develop a more complete understanding of patterns that exist within the error descriptions for particular error types enabling the analysis of collaborative human errors to be conducted.

*Future Change 4.2: Develop and validate a structured method for rigorously applying the classification model.*

Developing a structured method for applying the classification model was not in the scope of this research. The application framework was devised to add an element of structure to the application and ease the evaluation of the classification model for its development. Although the development of the application framework allowed a structured application of the classification model it may not have been the optimal approach. Work is required to develop a method for rigorously applying the classification model. Creating this method would enable a more comprehensive analysis to be conducted as described in Change 4.1 and improve the consistency of the application and description of contextual elements.

*Future Change 4.3: Extending the model to address aspects of collaborative error recovery*

The classification model could be extended further to address how people collaborate with other people and machines to recover from collaborative human error. Issues of collaboration in error recovery have been researched in terms of using conversation analysis (Frohlich 1999). Further work could be conducted in the use of conversation analysis in terms of the classification model developed in this research.

*Future Change 4.4: Use the classification model to learn more about the patterns that exist from the classification make-up of an erroneous situation.*

The analysis of the error examples in the WitStaffs studies began to examine patterns of error classifications and how they related to the type of error being examined. The studies indicated that certain types of erroneous situation yielded certain types of error classification. Further work could be conducted to extend the research to use the classification model to learn more about patterns of collaborative human error occurrence. This work would examine if any conclusions can be drawn from the mix of classification types that describe an erroneous situation. This type of study would act to address whether collaborative human errors are random or whether there are common causal mechanisms that result in similar types of erroneous situations.

*Future Change 4.5: Extend the use of the classification model to assist in the design of error defences against collaborative human errors.*

In Reason (1997) there are a lot of references to the defences that humans and organisation design to guard against collaborative human error. These defences either attempt to prevent them from occurring at all or reduce the criticality of the consequence when they do occur. Further work could be done on using the classification model as an aid for designing error defences on collaborative environments and the effect that collaboration has on the introduction of defences and how it impacts issues such as risk homeostasis.

*Future Change 4.6: Produce software to assist the creation of the error descriptions and automate the analysis process.*

The process involved in forming the error descriptions is a time consuming and complex task. Producing a tool to assist in this process would improve the ease and speed in which this task can be performed. The tool would require the creation of a more structured method of applying the classification as described in Change 4.2 to ensure that the most effective approach to forming the error descriptions is used. This software tool could also be used to automate the comprehensive analysis feature as described in Change 4.1.

## 7.5 Summary

This chapter has described the third phase of this research and has discussed how the studies conducted in this research have contributed to building an understanding of collaborative human error. The first section explored the application of the classification model on the collaborative diagram building task. The second section describes how the diagram building study contributed to the development of the classification model by focusing on low-level errors. The third section describes the application of the classification model to the implementation and use of the WitStaffs groupware environment. The final section described how the WitStaffs study contributed to the development of the research by looking at an erroneous situation that involved and demonstrated the entire scope of the model.

The findings from all of the studies presented in this research have contributed to the development of the classification model and the application framework. The outcomes of these studies were described in Chapter 4.

The following chapter concludes this thesis by reviewing the work that was conducted and how it addresses the objectives set for this research and its contribution to the domains of collaborative systems and human error.

# Chapter 8

# 8 Conclusions

This thesis has presented a classification model for collaborative human error that has been created to provide a means for understanding human error in collaborative systems. The aim of this research was to examine the occurrence of human error in collaborative systems and to identify ways in which human error can be examined with an emphasis on collaborative systems. This aim was addressed by creating a model of collaborative human error and a classification for its description that was evaluated through its application in human error case studies.

It was realised early on that current definitions of human error are not effective when examining human error in collaborative environments. This is because they do not include the important contextual information that describes the physical and emotional conditions in which different collaborators are working. These factors have a major impact on the occurrence of human error in these environments. The model of collaborative human error describes how collaborative human errors can be examined at three contextual levels including social context, situation context and local interaction context. At each level is a product which is a goal, plan and task respectively. The model states that a collaborative human error occurs when there is a conflict between contextual elements at each level that prevent the product from occurring. The elements that make up the classification reflect this statement.

Chapter 3 describes the basis for a model of collaborative human error following the literature review in Chapter 2. The chapter examines examples of human errors that involve some form of collaboration. The examples were examined in relation to how components of human error relate to the concepts present in Mantovani's framework for collaborative systems. From this examination the basis of a model of collaborative human error was devised that proposed a new approach to the examination of human error in collaborative systems.

Chapter 4 describes the model of collaborative human error and an associated classification that was developed through the research described in this thesis. The model includes new definitions for collaborative human error, a definition of the scope of study and a model for how human errors occur in collaborative systems. The classification provides a mechanism with which different types of human errors can be grouped. To aid in applying the classification model an application framework was created. The application framework describes a framework of traditional techniques with which the classification model could be applied to collaborative human errors in a structured manner.

Chapter 5 described the three phase approach that was adopted to develop the classification model and application framework. The chapter begins by describing the initial development of the model and classification and the objectives of Phase 1. The chapter then describes Phase 2 by giving a synopsis of each study, by describing its objectives, the reasons for the study and why it was selected for this research. The chapter finally describes Phase 3 by stating its objectives, a description of each error example and how the errors were observed.

Chapter 6 and 7 describe the development of the classification model and application framework through their application to examples of collaborative human error. Chapter 6 describes the development through the application to established paper-based case studies. Chapter 7 describes the development through the application on observed examples of collaborative human error.

This chapter reflects on the work conducted in this research by considering the contributions it provides to the field of human error and the study of collaborative systems. The chapter begins by reviewing the objectives of the work stated in Chapter 1 and how these objectives have been addressed. Section 8.2 describes the contributions of this research to the human error and collaborative systems domains. The classification model are then examined in Section 8.3 in relation to a set of questions posed by Senders and Moray (1991) that address the understanding of human error resulting from this research. The final sections of this chapter propose areas for further research and give some final remarks about the work described in this thesis.

## 8.1 Re-Visiting the Objectives

The primary objective of the work reported in this thesis was to examine the occurrence of human error in collaborative systems and to identify ways in which human error can be examined with an emphasis on collaborative systems. The approach adopted to address this objective was to create a classification model by which human errors in collaborative systems can be examined. To aid in the application of the classification model a framework was created for its application to the analysis of case studies.

This primary objective was broken down into four objectives which are re-examined in the following sections.

### 8.1.1 Objective 1

*"Examine the occurrence of human error in collaborative systems to identify the issues involved in adopting a collaborative focused approach."*

Chapter 2 reviews the literature in both collaborative systems and human error to identify the issues involved with examining human error in collaborative systems. The chapter examines collaborative systems from three levels of context which consist of social context, situation context and local interactions. These three levels encompass a holistic approach to examining concepts of collaborative system use. The second part of Chapter 2 examines human error in relation to error theories, classifications, methods for their analysis and the applications that result from a human error analysis can be used for. This chapter identifies many issues present in collaborative systems that complicate the examination of human error. The review of human error examines the ability of current theories to examine human error in collaborative systems and identifies important application areas that should be supported by a human error approach.

The review identifies the issues that impact upon the study of human error through the temporal and spatial distribution of the users in collaborative systems. The study of human errors is complicated due to the influence that social and situational context, present in collaborative systems, have on cause and effect chains, intention, latency, individual behaviour and defence mechanisms. These issues are explored and examined through the applications of the classification model in Chapters 6 and 7.

### 8.1.2 Objective 2

*"To present a developed understanding of how human errors occur in collaborative systems within a classification model."*

This second objective is addressed through the examination of human error scenarios in relation to a framework of collaboration to create a classification model that can be used to increase our understanding of collaborative human errors.

This began with the examination of the collaborative model in regards to a test example of human error and a brief examination of two reported studies as reported in Chapter 3. From this examination it was possible to develop the basis for a model for the study of human errors in collaborative systems and to develop a classification.

The examination continued by conducting a more detailed application of the concept model to the Kegworth Accident and the LASCAD system failure as reported in Chapter 6. Through the examination described in Chapter 6 the classification model was defined and clarified through the increased understanding of human errors in collaborative environments that was developed through the studies.

The classification model developed was applied to further examples of collaborative human error to consolidate the understanding of collaborative human errors that had been developed as described in Chapter 7. Through studying how human errors occur in relation to different elements of a collaborative framework it was possible to gain an understanding of how the mechanisms existing within the model of collaboration impacted upon the occurrence of human error. The case study approach helped to develop the understanding of human error in collaborative environments that is encompassed within the classification model described in Chapter 4.

### 8.1.3 Objective 3

*"To demonstrate how a collaborative systems focus can be used in the examination of human errors in real world environments."*

Chapter 6 examines the model of collaborative human error by applying the concepts present in the framework and taxonomy to paper-based case studies consisting of the Kegworth accident and the LASCAD system failure case studies.

In the Kegworth Accident study the classification model was applied by simply identifying the errors using a task analysis and applying the classification to them. This was sufficient at this early stage of the research but it was envisaged that a more structured approach would be required for the study of larger, more complex case studies such as the LASCAD study. A set of techniques was selected for gathering and organising the contextual data and for forming the error descriptions that encompassed the classification elements. These were adapted during the LASCAD case study to make them applicable to the model of collaborative human error and to improve their integration with each other.

The application framework that was formed during the LASCAD study and applied to the observed case studies illustrates an approach by which the classification model can be used for the examination of collaborative human error. The examination in Chapter 6 and Chapter 7 demonstrate that the classification model could effectively be applied for the examination of collaborative human error.

### 8.1.4 Objective 4

*"To identify the issues of applying the model of collaborative human error on human error analysis. This explores the validity of the model, the issues of its application and the applications in which such an approach can be utilised effectively."*

Through the applications of the classification model, as described in this research, it became apparent that a collaborative approach maintains validity but has significant implications for the study of human error. The studies also showed the application of the model to a variety of different collaborative technologies and environments. The details of this objective relative to the studies conducted in this research are summarised below and the broader issues relating to this objective are discussed in section 8.3.

Through this research the fundamental concepts of the model have been applied, at varying levels of detail, to different examples of collaborative human error ranging from large organisational errors to low-level interaction errors. These studies began by testing the fundamental concepts of the model to develop the model of collaborative human error and the basis for the classification using a basic application of the classification model. The studies then examined the classification model in regards to reported and observed examples of human error. The observed examples of human error consisted of complex organisational examples of collaborative human error and a selection of small low-level behavioural errors. These subsequent examples of human error were examined in a higher level of detail and were used to iteratively develop, refine and validate the classification model. These studies reinforced the validity of the model as an approach for examining human error. However, the application of the classification model to the low-level examples of human error illustrated that more work needs to be conducted to study behavioural aspects of collaborative human error.

It became apparent through this research that the model of collaborative human error has significant implications for the study of human errors. These include the following:

1) The need for new definitions of human error;
2) An increased scope of study; and
3) A rigorous method by which it can be applied.

The studies indicated that current definitions for human error were not applicable within the model of collaborative human error and new definitions were required. The main reason for this was the realisation that collaborative human errors are not individual events but are situations that occur over a period of time and have a prolonged period of cause and effect. This led to a revision of the definition of the terms "collaborative human error" and "erroneous situation" as described in Chapter 4.

A collaborative focus to the study of collaborative human error increases the scope of study that is conducted. This is also true of human error research that considers contextual information in the examination of human error. The model of collaboration requires contextual information relating to organisations, groups and individuals that can span days, months or years depending on the scale of the study. This information is required to understand the context in which a collaborative human error occurs, how that contextual situation came to be and the consequences that it has.

The application of the classification model in this research was conducted using a framework of techniques defined through the studies. This framework allowed the information to be structured in a logical manner that allowed the important elements to be extracted and formed into the error descriptions that incorporate the classification. The structured application aided in maintaining an element of consistency when describing the contextual elements that aided classification and analysis. Further work needs to be conducted to examine a more formal methodological approach to applying the classification model.

The studies of collaborative human error illustrate the application of the model on a variety of different collaborative environments involving a variety of technologies. These include situations where agents are either co-located or remote and where agents are working either synchronously and asynchronously. A variety of technologies have also been examined including flight deck controls and radio communication, computer aided despatch systems, text chat systems, video conferencing, email and shared workspaces. The model was seen to apply to all of these collaborative situations and technologies. Further work needs to be conducted to examine the full implications of collaborative human error for a variety of technology types.

This section has reviewed the objectives of the research that were stated in Chapter 1 of this thesis. The following section summarises the contributions that were realised through addressing these objectives.

## 8.2 Summary of Contributions

The objectives of this research were realised within three main contributions that include the model, the classification and the framework with which they are applied. The model and classification combined form the classification model. Each of these contributions is summarised in the following sections.

### 8.2.1 The Model of Collaborative Human Error

***The first contribution of this research is the model of collaborative human error.*** The model of collaborative human error was created as an approach to realise the understanding of collaborative human errors that has been acquired through this research. The model comprises four main parts that included the following:

1) A high-level classification model for describing collaborative human errors;
2) The scope of study involved in the model of collaborative human error;
3) A model describing collaborative human error occurrence; and
4) Key definitions to be included in the model of collaborative human error.

The model of collaborative human error illustrates that collaborative human errors can occur at each of the three levels. At level 1 there are social conflicts, at level 2 there are planning conflicts and at level 3 there are local interation errors. An error at each level arises from a conflict occurring between elements existing at each respective level that apply to either multiple or individual agents. This forms the basis of the classification as summarised in the following section.

The model of collaborative human error encompasses a very broad scope of examination determined by the elements existing within the model ranging from a study of social context down to the local interactions that are performed. The model also includes collaboration failures between organisations, groups and individuals that are caused by events occurring days, months and even years prior to the erroneous situation under examination. The model does not only include errors involving collaboration but also encompasses single user errors.

The model of collaborative human error describes the elements occurring at each of the three contextual levels that include the level of social context, situation context and local interaction. The model is based upon the Mantovani's model of collaboration but some adaptations have been made in regards to the elements existing at each level to make it more applicable to studying human errors. The model also tracks the evolution of collaborative human errors through each level in regards to their cause, occurrence, consequence, detection and recovery.

The studies conducted in this research indicated that traditional definitions of human error could not be applied effectively when human errors are examined from a collaborative perspective. New definitions were created to define the terms "collaborative human error" and "erroneous situations" that would describe what a collaborative human error was and what it related to. These new definitions state what a collaborative human error is and acts to differentiate it from single user human errors.

### 8.2.2 The Classification of Collaborative Human Error

***The second contribution from this research was a mechanism by which collaborative human errors can be classified.*** The classification of collaborative human error distinguishes between three main human error types that relate to the three levels of context existing within the model. These high-level classification types include social conflicts, planning conflicts and local interaction errors. Each level is summarised below.

Social conflicts comprise conflicts between the goal, structure and history elements that form six error types. These six error types are Goal-Goal, Structure-Structure, History-History, Goal-Structure, Goal-History and History-Structure. The Goal is the product of interactions at this level and an error at this level is the conflict of elements that prevents the product from being achieved.

Planning conflicts comprise conflicts between the plan, opportunity and interest elements that form six error types. These six error types are Plan-Plan, Opportunity-Opportunity, Interest-Interest, Plan-Interest, Plan-Opportunity and Opportunity-Interest.

The Plan is the product of interactions at this level and an error at this level is the conflict of elements that prevents the product from being achieved.

Local interaction errors comprise four main error types that encompass Reason's skill, rule and knowledge-based error types and include technical failures. The error types at this level can apply to tools, users or tasks with the exception of technical failures that can only apply to tools.

This section has described the classification that is based on the model of collaborative human error. The following section describes the framework with which the classification model can be applied.

### 8.2.3 An Application Framework

***The third contribution of this research is a framework for applying the classification model.*** The application framework offered a structured approach to applying the classification model using a set of standard techniques that were adapted for this research. This application framework comprised common techniques and a common four-stage approach for application. The four-stage application approach encompassed knowledge acquisition, knowledge organisation, classification and analysis. This application framework was formed to provide a structure to the application but a methodology would be required to perform a more rigorous analysis of collaborative human error.

Knowledge acquisition involved the gathering of knowledge for the examination of collaborative human error. In this research a majority of the data was acquired from the details presented in text based accident and incident reports. However, in latter studies data was acquired from participation, observation, interviews and focus groups. Data acquisition was guided by the requirements of the model of collaborative human error.

The data was organised using two different but complementary tools. Firstly, the task data is structured using a task analysis method. In this research Groupware Task Analysis (GTA) was used. Secondly, the contextual data was structured within a series of context tables for each level of the model. Structuring the data aided in organising the case study into logical segments and assisted in forming the error classifications.

Errors identified from the task analysis were classified and included within an error description notation. This error description notation included the agents the error applied to, the task it relates to and the contextual elements that determine the classification type. These error description notations are grouped together to describe the erroneous situation under investigation. This notation makes it easier for the error descriptions to be analysed.

The error descriptions were analysed in this research by grouping together individual classifications according to their common elements. For example, the act of grouping classifications involving the same agent or object. This allows the erroneous situation to be examined in regards to the contribution that specific contextual elements had on its occurrence. This analysis can lead to further studies to examine the presence of contextual elements found to make a significant contribution to the erroneous situation.

It is not clear as to whether there would be consistency in the examination of collaborative human errors conducted by different analysts using this application framework. In this research the application framework was created to provide a structured approach to applying the classification. Consistency of examination was not an aim at this stage of the research but is something that should be examined more in further research.

This section has summarised the three main contributions arising from this research. The following section discusses areas where the study of human errors in collaborative environments could benefit from further work.

## 8.3 Discussion

This thesis has described the application of a classification model that was developed in this research. During the development of the classification model and its application much has been learnt about the impact of collaboration on the study of human errors.

This section describes the understanding of collaborative human error that has been achieved through this research.

The studies have described the application of the model of collaborative human error on examples of erroneous situations. These studies contributed to the development of an understanding of what collaborative human errors are and how they occur. Describing the understanding that has been gained in this research is achieved through addressing eight questions set by Senders and Moray (1991). The answers to these questions are addressed through examining the classification model in relation to the studies conducted in this research. The questions are as follows:

1) *Can there be a general theory of human error or is each error unique?*
2) *What is your approach to human error?*
3) *Are errors ever caused or are they always caused?*
4) *Are errors random? What do you mean by your reply?*
5) *Is there a common mechanism underlying all errors? A small number of mechanisms? Is there a mechanism for each error?*
6) *Does it make sense to distinguish between errors arising from internal sources (a lapse of memory, for example) and those arising from external sources (such as poor design of information displays)?*
7) *In what sense is a faulty design of a man-machine system a cause of a subsequent error of the actor?*
8) *What is an "error theory" a theory of?*

*Senders and Moray 1991*

Each of these questions is discussed in turn below in regards to how they impact upon the model, classification and our general understanding of collaborative human error.

*Question 1: Can there be a general theory of human error or is each error unique?*

It was stated in Senders and Moray (1991) that a theory of error is certainly possible and the same can be said for a theory of collaborative human error. The major question is the level of uniqueness that collaborative human errors have. There is divided opinion as to the extent in which errors are unique and require unique explanations. Due to the nature of human errors involving collaboration the extent to which these errors is unique was in even greater doubt.

The studies conducted in this research have shown that there are both common and unique aspects to human error. There are commonalities in that collaborative human errors can be described by elements within a classification using a small set of concepts and there are common patterns in regards to the error type and the classifications in the error descriptions that describe them but they are unique in terms of the context in which they occur. In this research the model of collaborative human error was effectively applied to a variety of different erroneous situations.

*Question 2: What is your approach to human error?*

The approach to human error in this research is that collaborative human errors occur through conflicting elements at three contextual levels. Errors can be classified according to the elements that are being conflicted with. This approach assumes that collaborative human error is an integral component of normal collaboration as defined by Mantovani (1996). This is assumed in the same way that a non-collaborative human error theory can be an integral part of a theory of behaviour. The study of collaborative human error involves the examination of processes and contextual situations leading to and resulting from an erroneous event.

A major factor emerging from this research is that collaborative human errors cannot be looked at independently of single user human errors. This is because a human error traditionally looked at from the perspective of a single person may be caused by events resulting from previous collaboration or may have an impact on a subsequent collaborative task. This meant that the classification model for collaborative human error had to include single user human errors.

The studies in this research have shown that a collaborative human error is not a single, self-contained event but is the occurrence of a situation that is not desirable to a human agent. In this research the term ‘agent’ refers to an individual agent, group or organisation. The examination of collaborative human error requires an understanding of the events that both precede and result from the erroneous situation. This determines the impact that collaboration has on the erroneous situation and how it impacts upon the success of subsequent collaborative tasks.

The findings from the case studies conducted in this research indicated that the approach to collaborative human error described in this research comprises the following points:

1. The model of collaborative human errors does not examine a single erroneous event but examines an erroneous situation, which can exist over any period of time, and its causes and impacts
2. The model of collaborative human errors examines erroneous situations using an adapted model of collaboration as opposed to more traditional behavioural theories
3. The model of collaborative human errors includes the examination of the contribution of contextual elements at three levels. These include social context, situation context and local interactions
4. The model of collaborative human errors classifies collaborative human errors according to conflicts between contextual elements applying to concepts existing within these three levels
5. The model of collaborative human errors examines the evolution of human error through these three levels
6. The model of collaborative human errors includes the examination of individuals working in groups, groups and organisations
7. The model of collaborative human errors involves the examination of historical or latent events that impact upon an erroneous situation.

In order to gain a more complete understanding of collaborative human error a structured application framework was used to apply the classification model. Knowledge was acquired that applied to the concepts existing within the model, this was organised into a series of context tables to describe the contextual situation in which the erroneous situation occurred. Errors were identified, classified and described in a notation to aid in understanding the impact of collaboration in regards to the erroneous situation. A structured method specifically for collaborative human errors has not been fully developed. The development of such a method may assist in improving our understanding of collaborative human error.

*Question 3: Are errors ever caused or are they always caused?*

The cause of an error is the presence of the necessary antecedents for an erroneous event. The studies conducted in this research highlight some interesting issues relating to causality. The studies suggest that there is no ultimate cause for human error but causal paths can be traced back infinitely. This means that human errors are always caused by previous human errors and the challenge is to determine the errors that have the most significance to the erroneous situation under examination. Each human error can be looked at as a causal factor, or a potential causal factor, for another human error that is, or could be, affected by it.

The model of collaborative human error identifies causal factors that contribute to an erroneous situation. Once these have been identified the relationships between these causal factors can be examined in order to determine what effect they have on the erroneous situation under investigation. It is these "effect" relationships between causal combinations that indicate possible reasons as to why the erroneous situation arose. For example, the LASCAD system failure was affected by six main tasks that included requirements specification, supplier selection, project management, system testing and implementation and human resources and CAD training. The study of collaborative human error should aim to discover how errors in each of these tasks impacted upon the events of the 26th and 27th October 1992. The LASCAD study examined the impacts of errors in the supplier selection task.

To answer the question addressed here, the model of collaborative human error assumes that human errors are always caused and that they are always caused by another error or by combinations of errors. The challenge in this type of study is deciding where to sensibly end the examination of the causal chain.

*Question 4: Are errors random? What do you mean by your reply?*

From the examination conducted in this research it cannot be said that errors are random or that if the same sequence of causal factors were to be present for a second time the same error manifestation might emerge. The emphasis on context and collaborations means that there are many variables existing in an erroneous situation. Every organisation is different, has different policies and work practices, has different work environments and every person is different in terms of their interests, their perception of opportunities or their relationships with other people. To establish the impact of these elements on the randomness of human error and to establish the predictive power of this approach to human error is a subject of further study.

*Question 5: Is there a common mechanism underlying all errors? A small number of mechanisms? Is there a mechanism for each error?*

If looking at collaborative human error from a behavioural perspective then there can be an 'almost infinite' number of error mechanisms as stated by Senders and Moray (1991) as seen below:

> *There may be a small number of error mechanisms that effect any one individual; there may be an almost infinite number when many individuals are considered.*
>
> *Senders and Moray 1991*

From the perspective of a model of collaboration the number of error mechanisms can be reduced to a manageable number. The application of the classification in this research suggests that there is a common mechanism underlying all collaborative human errors. The model of collaborative human error uses the concepts existing within a model of collaboration to reduce the number of possible human error mechanisms to fifteen classification types and a single related technical failure.

The work in these studies illustrated how the model of collaborative human error classified many events that would not normally be classified by a traditional human error classification. This occurs due to the increased number of mechanisms that can possibly cause an erroneous situation. These mechanisms need to be described in some way. The concepts existing within the original model of collaboration are altered to some extent in regards to 'Goals', 'Plans' and 'Tasks'. This restructuring had a further impact on the ability to distinguish between 'Plans' and 'Tasks'. During the case studies clear definitions were developed to distinguish between these concepts. The application of the classification in the case studies illustrated that the classification was possible and suggested that a common mechanism for collaborative human errors does exist.

The LASCAD study highlighted that other common mechanisms existed that could be described by different structures in the notation. In the early stages of this research it was assumed that a collaborative human error always involved a conflict between the concepts available to different agents. Applying the notation illustrated that this is not always the case and that different agents could collaborate but still produce an erroneous situation due to inappropriate concepts being present. These different error types were also observed in the WitStaffs study.

From the error descriptions created in the case studies the commonalities between the underlying mechanisms of collaborative human error can be examined. The ability for these descriptions to be analysed and produce interesting and useful information also suggests that the mechanisms are a valid way in which collaborative human errors can be examined.

*Question 6: Does it make sense to distinguish between errors arising from internal sources (a lapse of memory, for example) and those arising from external sources (such as poor design of information displays)?*

The nature of the model of collaborative human error means that it is important to focus on external contributions to collaborative human error. Internal sources can only be examined in regards to the single user errors related to the collaboration. The external factors indicate paths along which elements of causality can be examined. For example, it was the external factors that led to the identification of the following in the WitStaffs study:

1) The identification of reasons as to why it was difficult to find communal machines upon which to install the interface. These included a history of security problems, a lack of available machines and problems with software licenses; and
2) The identification of reasons as to why there were difficulties in the students expressing their opinions. These included an unreliable communication channel, a possible lack of IT experience, differing cultural backgrounds and experiences and their physical locations.

The identification of these external sources indicated appropriate directions that the examination could take. In the LASCAD and the WitStaffs studies these external sources were identified, at a high-level, from the task analysis. Not only did this direct the study, it also enabled it to be segmented into manageable sections.

Low-level errors were examined to explore collaborative human errors with a greater emphasis on the errors arising from internal sources. These studies demonstrated that the application of the classification model was possible. However, the limited size of the corpus restricted the understanding that could be gained of behavioural aspects of collaborative human error.

*Question 7: In what sense is a faulty design of a "man-machine" system a cause of a subsequent error of the actor?*

In the model of collaborative human error the faulty design of a man-machine system is assumed to be a conflicting element of context and thus is assumed to be a cause and a reason for a subsequent error of an actor. Reason (1997) defines this as a latent failure pathway. This does not only relate to human-machine systems but also includes the design of structures such as policies and guidelines. The designs of these elements were seen to be key factors contributing to erroneous events in the Kegworth, LASCAD and WitStaffs case studies.

In the Kegworth Accident there was a fault in the design of the training procedure in that it did not include the symptoms experienced during the flight. The omission of the actions necessary to address these symptoms led to the Commander drawing false conclusions based on his prior experience when diagnosing the fault. In addition to this the redesign of the Engine Instrument System (EIS) impacted upon the ability of the flight deck crew to acquire the correct information from it. Both of these design issues contributed to the erroneous fault diagnosis.

In the LASCAD case study the faulty design of a human-machine system was a major cause of the subsequent human errors occurring on the 26$^{th}$ and 27$^{th}$ October. The model of collaborative human error states that the faulty design of the LASCAD system was also a result of human errors. The faulty design was a result of a faulty structure chosen for the supplier selection process. The extent to which the faulty design of the LASCAD system resulted in subsequent human errors can be seen in Phase 3 of the LASCAD analysis (Appendix B5.3).

In the WitStaffs system the difficulties experienced in maintaining an open communication channel was contributed to by an inappropriate location chosen for the TeamWave server. The server was located in the UK but a majority of the contributing parties were in South Africa. This led to continuous network failures which made it very difficult for the groupware participants to communicate effectively.

*Question 8: What is an "error theory" a theory of?*

Error theories proposed in the past have included theories of particular error classes or based on theories of behaviour. The model of collaborative human error proposed in this research combines the skill, rule and knowledge-based error model by Reason (1990) within a model of collaboration.

In this research an error theory is a theory that describes what collaborative human errors are, how they can be described, how they occur and what is the coverage involved in their examination. These elements are illustrated by the definitions, model and classification presented in Chapter 4.

The realisation of the scope of collaborative human error, subsequent to the LASCAD case study, led to clearer definitions being required to determine what a collaborative human error was and of complementary terms that could help describe its occurrence. These definitions help describe what a collaborative human error is and that it contains an erroneous situation and that there is an evolution of collaborative human error.

The coverage of collaborative human errors is broad because it does not identify a single erroneous event but identifies an erroneous situation and its associated causes and impacts (the evolution of collaborative human error). The erroneous situation may contain individual erroneous events but they are seen as contributions to that situation. The causes and impacts can be both external and internal although the external factors are easier to determine as they are more observable. The external factors assist in tracing causality and latent failure pathways arising from contributions from organisations, groups or individuals. The internal factors examine how external factors impact upon erroneous actions in terms of skill, rule and knowledge-based behaviour.

## 8.4 Further Research

The work reported in this thesis has described the initial cycle of developing a classification model as a potential tool for examining human error in collaborative environments. This research opens up a number of areas for further research, not only to further develop the classification model as described in Section 7.4.3 in the previous chapter but also to examine its implementation into a method and to fully assess its application in different collaborative situations. This section describes these areas and considers wider issues that the development of the classification model has raised.

The areas that were identified to benefit from further research are listed below and then described in more detail.

1) Implementation of the model into an analysis method that facilitates a rigorous error examination for understanding cause, effect and providing possibilities for error prediction, error explanation and error remedy;
2) Explore the application of the classification model to a variety of collaborative technologies such as the Internet, mobile devices and communication devices;

3) Extend the classification model to address issues of collaborative error recovery how it can be used to assist in the design of error defences; and
4) Create a software tool for applying the classification model using a valid application method.

Each of these areas of further work is described in more detail below.

Implementation of the model into an analysis method that facilitates a rigorous error examination for understanding cause, effect and providing possibilities for error prediction, error explanation and error remedy. The application of the classification model in this research was conducted using a structure and a set of techniques that were established within the human error community. This allowed a structured application of the classification model to examples of collaborative human error. However, it can be assumed that the application of these elements through a more rigorous methodological approach would increase the richness of the results for an analysis and widen the scope of possible applications of those results. The creation of such a method could explore the possibilities of the classification model to be used to track cause and affect pathways; to predict situations that may be vulnerable to collaborative human error; to understand collaborative error remedy; or to improve information retrieval in accident and incident reports. This could be addressed through the exploration of the classification model in regards to a case based reasoning (Johnson 2000) examination of erroneous situations and the exploration of graphical methods by which the results of an analysis can be visualised

***Explore the application of the classification model to a variety of collaborative technologies such as the Internet, mobile devices and communication devices.***
Collaborative technologies have become commonplace in our everyday working and domestic lives. More and more information is being communicated using some form of technology channel. These channels have included the telephone, email, newsgroups, video conferencing, SMS text messages, meeting support tools and shared workspaces. The technology channels are also being communicated using a variety of devices such as mobile phones and PDA’s. The studies conducted in this

research have included some of these technologies but have not examined the aspects of collaborative human error that may be specific to certain collaborative technologies. The selection of a communication channel may depend upon its vulnerability to certain types of collaborative human error in certain tasks for which it is implemented. A study of specific collaborative technologies would help to create an understanding of how collaborative human errors occur and the vulnerabilities of the technology in certain task contexts.

***Extend the classification model to address issues of collaborative error recovery how it can be used to assist in the design of error defences.*** The scope of the examination of human error covered in this thesis was cause and effect. A further facet of human error not covered in this work is the impact of collaboration on error recovery. Work has already been conducted on the subject of error recovery in collaborative systems (Twidale and Marty 2000). The model of collaborative human error could be extended to address how people collaborate to undo, redo or perform a new action to recover from error using techniques such as conversation analysis (Frohlich et al 1994). Frohlich et al examined the use of conversation analysis to understand how humans communicate with computers to recover from error. Conversation analysis offers a collaborative approach to understanding the management of repair within the interactions of the user with the computer.

Human errors cannot be absolutely defended against in single user systems and this is even more true for collaborative systems. Once an accurate and detailed understanding of collaborative human error has been gained it is possible to understand how best to defend against their occurrence through their prevention and the management of their consequences. The classification model can be used to assist the design of error defences through reducing the number and complexity of modes that are present in a system; through improving the awareness and knowledge requirements of the users of collaborative technologies; through designing the interface to increase the users awareness of high risk environments; through the design of “forcing functions” to prevent the failure escalating before it has been corrected; or through the implementation of supervisory control ( Sarter and Woods 1995).

***Create a software tool for applying the classification model using a valid application method.*** The classification model reported in this thesis requires the collection, organisation, collation and analysis of large amounts of data. To ease this process and the management of the data a software tool could be developed to support the analysis of erroneous situations. Once the data is entered into the tool then the process of analysis and the management of data from a large error corpus can be automated. To create this software a more rigorous application method is required and potential analysis types need to be defined as described in the first area of further work listed in this section.

## 8.5 Final Remarks

This thesis has reported the creation of a classification model for collaborative human error. The research examines the impact of collaboration on the occurrence of human error and proposes a classification by which they can be described. This is an area that is relatively unexplored in the field of human error but is one that is becoming increasingly more important.

More and more organisations are investing in technologies facilitating collaboration to communicate information in many different forms including text, still images, video and audio. These include telemedicine systems (Pinelle, D., and Gutwin, C. 2002), video conferencing (Panteli and Dawson 2001) and asset management systems (i.e. Microsoft Sharepoint[2], Blue Order Media Workbench[3], and Sony MMS[4]) that facilitate synchronous and asynchronous information flow through an organisation's structure. An impact of this development is that the scope for collaboration increases as the distribution of information becomes more widespread. The increase of this information flow relies on successful collaboration and the presence of a common understanding between participants for these technologies to be effective. The growth of these

[2] http://www.microsoft.com/sharepoint/

[3] http://www.blueorder.com/products_media_work.html

[4] http://www.sonybiz.net/mms

technologies and the importance of effective collaboration are being recognised by many organisations that are creating mechanisms to facilitate effective communication through the introduction of standards and the use of metadata. For example, the BBC have created a communication standard called SMEF (Standard Media Exchange Format). SMEF is a data model that defines a common language to enable everyone who receives certain information to be able to understand and use it (BBC 2002).

The form in which human errors present themselves is constantly changing just as changes occur in the technology in which they occur. This means that increasing our understanding of how human error occurs is a constant area for research. The improvements in communication technology mean that distributed collaboration becomes more commonplace and collaboration plays a much greater role in the causes and reasons for human errors. It is increasingly important for collaboration to be a major consideration in the examination of erroneous situations.

# References


Abreu, J., Almeida, P. and Branco, V. (2001) 2BeOn - Interactive television supporting interpersonal communication. *Proceedings of the 6$^{th}$ Eurographics Workshop on Multimedia*. Manchester, UK, September 8-9. *The European Association for Computer Graphics*

Ackerman, M. (2000). The Intellectual Challenge of CSCW: The Gap Between Social Requirements and Technical Feasibility. *Human-Computer Interaction,* 15(2-3), 181-205.

Air Accidents Investigations Branch (AAIB) (1997). *Department of Transport. Report On an Incident near Lambourne VOR: Boeing 747 and GulfStream G IV on 3$^{rd}$ July 1997.* London, United Kingdom, Her Majesty's Stationery Office (Number 4/99).

Air Accidents Investigations Branch (AAIB) (1996). *Department of Transport. Report On The Boeing 737-400 G-OBME Near Daventry, on 23$^{rd}$ February1995.* London, United Kingdom, Her Majesty's Stationery Office (Number 3/96).

Air Accidents Investigations Branch (AAIB) (1990). *Department of Transport. Report On The Accident To Boeing 737-400 G-OBME Near Kegworth, Leicestershire on 8th January 1989.* London, United Kingdom, Her Majesty's Stationery Office (Number 4/90).

Baxter, G. D. and Bass, E. J. (1998). Human Error Revisited: Some Lessons for Situation Awareness. In *Proceedings of the Fourth Annual Symposium on Human Interaction with Complex Systems.* Los Alamitos, *CA: IEEE Computer Society Press,* 81-87

BBC (2002). *SMEF: Standard Media Exchange Format Data Model.* http://www.bbc.co.uk/guidelines/smef/

Bés, M-O. (1997). Analysis of a human error in a dynamic environment: The case of air traffic control. In *Proceedings of the workshop on human error and systems development,* Glasgow.

Beynon-Davies, P. (1999) Human error and information systems failure: the case of the London ambulance computer aided dispatch system project. *Interacting With Computers,* 11, 699-720

Beynon-Davies, P. (1995). Information systems `failure': case of the LASCAD project, *European Journal of Information Systems,* 1995

Blandford, A. and Goode, J. (1998a) Introduction to programmable user modelling in HCI. *Tutorials at HCI'98 at Sheffield Hallam University,* AM3

Blandford, A. and Goode, J. (1998b) Programmable user modelling analysis in practice. *Tutorials at HCI'98 at Sheffield Hallam University,* PM13

Bogner M.S. (1995) Human Error Identification: Designing for the Users, *Proceedings of the FAA Workshop on Flight Crew Accident and Incident Human Factors.* Washington, D.C.: Office of System Safety, FAA

Cadiz, J.J., Balachandran, A. Sanocki, E. and Grudin, J. (2000) Distance Learning Through Distributed Collaborative Video Viewing. *Proceedings of CSCW 2000,* 135-144.

Chambers, C., Croll, P.R. and Bowell. M. (1999) A study of incidents involving programmable electronic safety-related systems. *Interacting With Computers,* 11, 597-609

Collins, R.W. (1995) CSCW: an opportunity for action research. *Proceedings of conference on Organizational computing systems*, August 13 - 16, 1995, Milpitas, CA USA, 162-167

Dekker, S., Fields, B., Wright, P. (1997) Human Error Recontextualised. *Workshop on Human Error and Systems Development.* Glasgow, March 1997.

De Michelis, G., Dubois, E. and Jarke, M. (1997) Cooperative information systems: A Manifesto. *Cooperative Information systems: Trends and Directions,* Mike P. Papazoglou and Gunter Schlageter (eds), Academic-Press.

Dix, A., Finlay, J., Abowd, G. and Beale, R. (1998). *Human-Computer Interaction (2nd Edition).* Prentice Hall International (UK).

Dix, A., Mancini, R. and Levialdi, S. (1996) Alas I am undone – Reducing the risk of interaction. *In Proceedings of HCI'96 (Adjunct Proceedings)*. Imperial College, London, 51-56.

Dix, A. J. (1994). Computer-Supported Co-operative Work - A Framework. *In 'Design Issues in CSCW'*. Eds. Rosenburg, D. and Hutchison, C. Springer Verlag, 9-26.

Ellis, C.A. and Weiner J. (1994). Goal-based models of collaboration. *Collaborative Computing,* 1, 61-86

Endsley, M.R. (1995) Towards a theory of situation awareness in dynamic systems. *Human Factors,* 37: 5-19.

Felciano, R. M. (1995) *Human Error: Designing for Error in Medical Information Systems: or "Don't worry--it always beeps when you do that!"* talk given at a graduate seminar at Stanford University School of Medicine http://www.smi.stanford.edu/people/felciano/research/humanerror/humanerrortalk.html

Fields, B., Wright, P. and Harrison, M. (1997). THEA: Human error analysis for requirements definition. *University of York Computer Science Technical Report* 294, 1997.

Fields, R.E., Wright, P.C. and Harrison, M.D. (1995) A task centred approach to analysing human error tolerance requirements. *Proceedings of RE'95 - Second IEEE International Symposium on Requirements Engineering.*

Finkelstein, A. & Dowell, J. (1996) A Comedy of Errors: the London Ambulance Service case study. *In Proceedings of 8th International Workshop on Software Specification & Design* IWSSD-8, IEEE CS Press, 1996, 2-4.

Frohlich, D., Drew, P and Monk, A. (1994) Management of repair in human-computer interaction. *Human-Computer Interaction,* 1994, 9, 385-425.

Greenberg S. and Roseman, M. (1998). *Using a Room Metaphor to Ease Transitions in Groupware.* Research report 98/611/02, Department of Computer Science, University of Calgary, Calgary, Alberta, Canada, January. http://cpsc.ucalgary.ca/grouplab/papers/

Greenberg, S. (1991) Personalizable groupware: Accomodating individual roles and group differences. *Proceedings of the ECSCW '91 European Conference of Computer Supported Cooperative Work*, Amsterdam, Kluwer Academic Press, 17-32

Grudin, J. (2002) Group Dynamics and Ubiquitous Computing. *Communications of the ACM,* 45 (8), 74-78

Grudin, J. (2001) Desituating Action: Digital Representation of Context. *Human-Computer Interaction,* 16 (2-4), 269-286

Grudin, J. and Palen, L., (1995). Why Groupware Succeeds: Discretion or Mandate? *Proc. ECSCW'95,* Dordrecht, The Netherlands: Kluwer, *263-278.*

Grudin, J. (1988) Why Groupware applications fail: Problems in design and evaluation, *Office: Technology and people,* 4 (3), 245-264

Grudin, J., 1987. Social evaluation of the user interface: Who does the work and who gets the benefit? *Proceedings of INTERACT'87.* Amsterdam: North-Holland, 805-811

Gunter, K. (1998). OACIS: Object orientated analysis for collaborative information systems. Thesis (PhD). the University of Manchester.

Gutwin, C. and Greenberg, S.(2001) A descriptive framework of workspace awareness for real-time groupware. *Computer Supported Cooperative Work (CSCW), The Journal of Collaborative Computing*, Kluwer Academic Press

Gutwin, C., Stark, G. and Greenberg, S. (1995) Support for workspace awareness in educational groupware. *Proceedings of CSCL'95.*

Hancke, T.: The Design of Human-Machine-Systems: The Example of Flight Decks. Aachener Reihe Mensch und Technik 13, Aachen, 1995

Hughes, J.A., Randall, D. & Shapiro, D. (1992) Faltering from ethnography to design. CSCW 92: sharing perspectives: Turner & Kraut (Eds.) *Proceedings of the Conference on Computer supported Cooperative Work,* October 31 to November 4, Toronto, Canada. N.Y.: ACM Press, 115-122.

Hollnagel, E. (1993). *Human Reliability Analysis: Context and Control.* Computers and People series, Academic Press.

Johnson, C.W. (2001) The London Ambulance Service, Computer Aided Despatch System: A Case Study in the Integration of Accident Reports and the Constructive Design of Safety-Critical Computer Systems. *Reliability Engineering and Systems Safety,* 71 (3), 311-326

Johnson, C. W. (2000). Using Case-Based Reasoning to Support the Indexing and Retrieval of Incident Reports. *Proceedings of European Safety and Reliability Conference (ESREL 2000): Foresight and Precaution.*

Johnson, C.W. (1999a) Improving the Presentation of Accident Reports over the World Wide Web. Proceedings of the 17th International Systems Safety Conference, J. Dixon (Eds.), *The Systems Safety Society*, *Unionville, Virginia, United States of America,* 396-405.

Johnson, C.W. (1999b). Why Human Error Analysis Fails to Help Systems Development. S*pecial edition of Interacting With Computers on human error, Elsevier Science.*

Johnson, C.W. (1998). Representing the Impact of Time on Human Error and Systems Failure. *Interacting with Computers,* 11,

Johnson C.W. (1997) Proving Properties of Accidents. 4th NASA Langley Formal Methods Workshop, Ed. C.M. Holloway and K.J. Hayhurst (Eds), *No. NASA Conference Publication 3356*, , NASA Langley Research Centre, Hampton, United States of America, 21-34

Jones, S. and Marsh, S. (1997) Human-Computer Interaction: Trust in CSCW. *SIGCHI Bulletin, 29* (3)

Katz, L.A., Thatcher, A. and Trepess D. (1999) The Impact of Computer Mediated Communication (CMC) on Conflict Resolution. *In the proceedings of INTERACT '99,* 2, 41-42

Kirwin, B. (1992). *Task data collection methods.* E. Kirwin, & L. K. Ainsworth (Eds), A guide to task analysis. London, UK: Taylor & Francis.

Klöckner, K. (2002) *BSCW:* Cooperation Support for Distributed Workgroups. *Proceedings of the 10th Euromicro Workshop on Parallel, Distributed and Network-based Processing*. Vajda, Ferenc[Hrsg.], (2002), p. 277 - 282

Leveson, N.G. (1995) *Safeware: System safety and computers.* Addison-Wesley Publishing Company, Massachusetts.

Liu, K. and Dix, A. (1997). Norm governed agents for CSCW. *1st International Workshop on Computational Semiotics,* Paris.

Ljungstrand, P. (2000) Context-awareness in distributed communication systems. Workshop paper, "The What, Who, Where, When, Why and How of Context-Awareness" *workshop, Computer-Human Interaction (CHI) 2000*, The Hague, The Netherlands.

Love, L. and Johnson, C.W. (1997) Using Diagrams to Support the Analysis of System 'Failure' and Operator 'Error'. *People and Computers XII: Proceedings of HCI'97. H. Thimbleby and B. O'Conaill and P. Thomas (Eds),* Springer Verlag (Pub.), London, United Kingdom, 245-262.

Mantovani, G. (1996). Social Context in HCI: A new framework for mental models, co-operation, and collaboration. *Cognitive Science,* 20.

Maurino, D., Reason, J., Johnston, N., and Lee, R. (1995). *Beyond aviation human factors*. (Pub.) Avebury aviation.

May, J, Johnson, P. Wild, P, Johnson, H and Gamble, T. (2001) TICKS Workshop: Modelling multiple and collaborative work tasks. *In Proceedings of HCI2001/IHM,* Lille, France, September 11th 2001

McCarthy, J.C., Healey G.T., Wright, P.C. and Harrison, M.D. (1997). Accountability of work activity in high-consequence work systems: human error in context. *Int. J. Human-Computer Studies,* 47, 735-766.

Monk, A.F. and Gilbert, N. (1995). *Perspectives on HCI: Diverse approaches.* Computers and People series, Academic Press.

Moray, N. (1990). Dougherty's dilemma and the one-sidedness of human reliability analysis (HRA). *Reliability Engineering and Systems Safety,* 29, 337-344

Nardi (1996) *Context and Consciousness: Activity Theory and Human-Computer Interaction.* MIT Press.

Newman, N. and Newman, R. (1992) Two failures in Computer-mediated text communication. *Instructional Science,* 21: 29-43

Ngwenyama, O. K. and Lyytinen, K. J. (1997). Groupware environments as action constitutive resources: A social action framework for analyzing groupware technologies. *Computer Supported Cooperative Work: The Journal of Collaborative Computing,* Kluwer Academic Publishers, *6*, 71-93.

Norman, D. A. (1981). Categorisation of action slips. *Psychological Review,* 88.

Norman, D.A. (1999). *The invisible computer: Why Good Products Can Fail, the Personal Computer Is So Complex, and Information Appliances are the Solution.* The MIT Press.

Pankoke-Babatz, U., Klöckner, K., & Jeffrey, P. "Norms and Conventions in Collaborative Systems". In Bullinger, H. Ziegler, J. *In Proceedings of HCI International '99,* August 22-27, 1999. Munich, Germany, 2, 313-317.

Panteli, N., Dawson, P. (2001). Video Conferencing Meetings: Changing Patterns of Business Communication, New Technology, Work and Employment, 16 (2).

Pinelle, D., and Gutwin, C. (2002) Groupware Walkthrough: Adding Context to Groupware Usability Evaluation. *In Proceedings of CHI 2002*

Pocock, S., Harrison, M., Wright, P & Johnson, P. (2001) THEA: a technique for human error assessment early in design. *In Proceedings Interact'01*, Japan.

Poltrock, S., Grudin, J., Dumais, R., Fidel, R., Bruce, H. and Pejtersen, A.M. (2002) Information seeking and sharing in design teams, http://research.microsoft.com/users/jgrudin/

President's Commission (1979) *The Accident at Three Mile Island - The Need for Change: The Legacy of Three Mile Island;* Washington, D.C., U.S. Government Printing Office.

Rasmussen, J. (1987). *The definition of human error and a taxonomy for technical systems.* New Technology and Human Error, New Technology and Work, Wiley Series, Ed. Rasmussen J., Duncan, K. and Leplat, J.

Reason, J. (1997). *Managing the risks of organizational accidents*. Ashgate Publishing Ltd. Hants. UK.

Reason, J. (1990). *Human error. Cambridge,* M.A: Cambridge University Press.

Reason, J. (1987). A framework for classifying errors. Eds. Rasmussen J., Duncan, K. and Leplat, J, *New Technology and Human Error, New Technology and Work,* John Wiley & Sons Ltd

Rizzo A., Parlangeli O., Marchigiani E. and Bagnara S. (1996). The management of human errors in user-centered design. *SIGCHI,* 12, 312-320.

Robinson, M. (1991) Computer-supported co-operative work: cases and concepts. *Readings in Groupware and computer-supported co-operative work: Assisting human-human collaboration.* Pub. Morgan Kaufmann, Baeker, R. M.

Salvador, T., Scholtz, J. and Larson, J. (1996). The Denver Model for groupware design (Yeeeee Haaaaaa!). *SIGCHI Bulletin,* 28 (1).

Sanderson P.M. and Harwood K. (1988) *The Skills, Rules, and Knowledge Classification: A Discussion of its Emergence and Nature, in Tasks, Errors, and Mental Models,* Eds. Goodstein, L.P., Andersen, H.B., and Olsen, S.E, Taylor and Francis Ltd.

Sarter, N. and Woods, D.D. (1997). Teamplay with a Powerful and Independent Agent: A Corpus of Operational Experiences and Automation Surprises on the Airbus A-320. *Human Factors,* 39, 553—569.

Sarter, N. and Woods, D.D. (1995) "How in the world did we get into that mode?" Mode error and awareness in supervisory control. *Human Factors*, 37, 5-19.

Senders, J.W. and Moray, N.P. (1991) *Human error: Cause, prediction, and reduction.* Lawrence Erlbaum Associates, New Jersey

Sheen, Mr Justice (1987), *Report of Court No. 8074; mv Herald of Free Enterprise*, HMSO, London, 1987.

Schreer , O, Kauff, P. (2002) "An Immersive 3D Video-Conferencing System Using Shared Virtual Team User Environments", *In Proceedings of ACM Collaborative Environments, CVE 2002,* Bonn, Germany, Sept./Oct. 2002.

Smith, D. (1996) On a wing and a prayer? Exploring the human components of technological failure. *Proceedings of Disaster '96, Electronic communication and disaster management* http://www.mcb.co.uk/services/conferen/jun96/disaster

South West Thames Regional Health Authority (1993). *Report of the Inquiry into the London Ambulance Service*, ISBN 0 905133 70 6, February 1993, available from: Communications Directorate, South West Thames Regional Health Authority, 40 Eastbourne Terrace, London W2 3QR, England

Stockman A. G., Ingeldew M., Trepess D. W., Gunter K. and Nie M (2000) An investigation into the requirements for computer supported cooperative project management, *In Proceedings of BIT 2000: Business Information Technology Management: E-futures,* Manchester, November 2000.

Suchman, L. (1987) "Plans and Situated Actions", *MIT Press*

Swain, A.D. and Guttman, H.E. (1983) Handbook of human reliability analysis with emphasis on nuclear power plant applications. *Technical Report, NUREG/CR-1278, Sandia National Laboratory, N.M.*

Terzis, S, Nixon, P. (1999) Building the next generation groupware: A survey of groupware and its impact on the virtual enterprise, *Technical report of Trinity College Dublin, Computer Science Department, TCD-CS-1999-08, February*

Thatcher, A., Katz, L-A. & Trepess, D. (2000). Teaching CSCW in developing countries through collaboration. *SIGCHI Bulletin*, 32(1), 63-66

Thatcher, A., Miller, K. and Trepess, D. (1997). The advantages and problems of using the world wide web as an aid in teaching organisational behaviour: Comparisons between SA and UK OB graduate students 1997. *International organisational behaviour teaching conference,* Graduate Business School, University of Cape Town.

Trepess, D. and Stockman, A. (1999) A classification and analysis of erroneous actions in computer supported co-operative work environment. *Interacting With Computers,* 11, 611-622.

Trepess, D. and Stockman, A. (1998). A framework for erroneous actions in Computer Supported Cooperative work. *Proceedings of the NETIES'98 conference,* Leeds Metropolitan University.

Twidale, M,B. and Marty, P.F (2000). Coping with errors: the importance of Process Data in Robust Sociotechnical Systems. *Proceedings of CSCW'00,* December 2-6, 2000, Philadelphia, ACM Press

Van der Veer, G.C. and Van Welie, M. (1999) Groupware Task Analysis, *Tutorial Notes for the CHI99 workshop "Task Analysis Meets Prototyping: Towards seamless UI Development",* 16th May 1999, Pittsburgh PA, USA

Van der Veer, G.C., Lenting, B.F. and Bergevoet, B.A.J. (1996) GTA: Groupware Task Analysis - Modeling Complexity. *Acta Psychologica,* 91, 297-322.

Viller, S., Bowers, J. and Rodden, T. (1999) Human factors in requirements engineering: A survey of human sciences literature relevant to the improvement of dependable systems development processed. *Interacting With Computers,* 11, 665-698.

Woods, D. D. (1996). Decomposing automation: Apparent simplicity, real complexity. In R. Parasuraman and M. Mouloua, (Eds.), *Automation technology and human performance*, Hillsdale, NJ: Erlbaum, 3-17.

Woods, D.D., Johannesen, L., Cook, R.I. and Sarter, N. (1994) *Behind Human Error: Computers, Cognitive Systems, and Hindsight.* Crew Systems Ergonomics Information and Analysis Center, Wright-Patterson AFB, OH.

# GLOSSARY

**Acronym:**

AAIB: Air Accident Investigation Branch

ATC: Air Traffic Control

AVLS: Automatic Vehicle Location System

BMA: British Midlands Airways

CAA: Civil Aviation Authority

CAD: Computer Aided Despatch

CAE: Consequence Analysis Evidence

CCD: Cause, Consequence Diagrams

CSCW: Computer Supported Collaborative Work

DFD: Data Flow Diagram

EIS: Engine Instrument System

EPC: Error Producing Conditions

FDC: Flight Deck Crew

FL: Flight Level

FSM: Flight Service Manager

GFT: General Failure Types

GL: Goal

GTA: Groupware Task Analysis

HIS: History

HP: High Pressure

IAL: International Aeradio Ltd

INT: Interest

IT: Information Technology

KB: Knowledge Based

LAS: London Ambulance Service

LASCAD: London Ambulance Service Computer Aided Despatch

MDT: Mobile Data Terminal

MUC's: Multiple User Consequences

OP: Opportunity

ORCON: Operational, Research Consultancy

PIF: Performance-Influencing Factors

PL: Plan

PUMA: Programmable User Modelling Analysis

RA: Resolution Advisory

RB: Rule Based

RHA: Regional Health Authority

RIFS: Radio Interface System

TCAS: Traffic Alerting and Collision Avoidance System

TF: Technical Failure

SA: Situation Awareness (In Chapter 2) South Africa (In Chapter 7)

SB: Skill Based

SFI: Standard Financial Instructions

SO: Systems Options

Staffs: Staffordshire University

STR: Structure

SUC's: Single User Consequences

UIR: Upper Information Region

UK: United Kingdom

WBT: Work Based Trainers

Wits: University of the Witswatersrand